



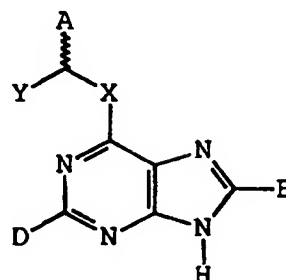
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: **CYCLIN DEPENDENT KINASE INHIBITORS**

## (57) Abstract

A range is disclosed of pyrimidine derivatives (I) which can act as inhibitors of cyclin dependent kinases (CDK's) and which thereby can provide useful therapeutic compounds for use in treatment of tumours or other cell proliferation disorders. The compounds of this invention bind to CDK molecules in a manner that appears to differ from that of known CDK inhibitors such as olomoucine and roscovitine. In formula (I), X is O, S or CHR<sub>x</sub> where R<sub>x</sub> is H or C<sub>1-4</sub> alkyl; D is H or NZ<sub>1</sub>Z<sub>2</sub> where Z<sub>1</sub> and Z<sub>2</sub> are each independently H, C<sub>1-4</sub> alkyl, C<sub>1-4</sub> hydroxyalkyl, optionally substituted aryl or optionally substituted aralkyl; A is selected from H, C<sub>1-4</sub> alkyl, C<sub>1-4</sub> alkoxy, hydroxy, CH<sub>2</sub>(CH<sub>2</sub>)<sub>n</sub>OH (n=1-4), and NR<sub>a1</sub>R<sub>a2</sub> where R<sub>a1</sub> and R<sub>a2</sub> are each independently H or C<sub>1-4</sub> alkyl; Y is or includes an optionally substituted 4- to 8-membered carbocyclic or heterocyclic ring; D' is H or NZ<sub>3</sub>Z<sub>4</sub> where Z<sub>3</sub> and Z<sub>4</sub> are each independently H, C<sub>1-4</sub> alkyl, C<sub>1-4</sub> hydroxyalkyl, optionally substituted aryl or optionally substituted aralkyl; E is selected from NO, NO<sub>2</sub>, N=N-Ar where Ar is an optionally substituted aryl or optionally substituted aralkyl, NR<sub>e1</sub>R<sub>e2</sub> or NR<sub>e1</sub>NR<sub>e2</sub>R<sub>e3</sub> (R<sub>e1</sub>, R<sub>e2</sub> and R<sub>e3</sub> each being independently H, C<sub>1-4</sub> alkyl, C<sub>1-4</sub> hydroxyalkyl, an optionally substituted aryl or an optionally substituted aralkyl), C(R<sub>e</sub>)=U (R<sub>e</sub> being hydrogen, C<sub>1-4</sub> alkyl or substituted alkyl, e.g. hydroxyalkyl, or an unsubstituted or substituted aryl or aralkyl, e.g. benzyl, and U being selected from O, NR<sub>e'</sub>, NOR<sub>e'</sub> and N-NR<sub>e'</sub>R<sub>e''</sub> where R<sub>e'</sub> and R<sub>e''</sub> are each independently H, C<sub>1-4</sub> alkyl or CONH<sub>2</sub>), T, CH<sub>2</sub>T, CHT<sub>2</sub> and CT<sub>3</sub>, where T is a halide I, Br, Cl or F.



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**CYCLIN DEPENDENT KINASE INHIBITORS****Field of the Invention**

The present invention relates to certain compounds, especially pyrimidine derivatives, which show activity in biological systems as cyclin dependent kinase (CDK) inhibitors and which are accordingly of interest as potentially useful therapeutic agents that may be incorporated in pharmaceutical compositions or formulations for use in controlling or inhibiting cell growth or proliferation in mammals, for example in connection with antitumour or cancer treatment.

**Background**

Cyclin dependent kinases (CDK's) are a family of enzymes which form complexes with other activating proteins known as cyclins to provide key regulatory factors that are involved in the control of growth and division in animal cells. More particularly, the progression of animal cells through the cell division cycle (G1, S, G2 and M phases) is regulated by the sequential formation, activation and subsequent inactivation of a series of CDK/cyclin dimer complexes which control passage past cell cycle checkpoints and transitions between successive phases of the cell cycle, with the CDK's acting as catalytic sub-units of the complexes.

There are in fact a number of different cyclin proteins which, like the different CDK's, form a somewhat

loosely related family of CDK-activating proteins; different CDK/cyclin complexes function at different stages of the cell cycle with sequential increase and decrease in cyclin expression during the cell cycle and cyclin degradation during M phase usually being an important factor in determining orderly cell cycle progression. Thus, progression through G1 to S phase in mammalian cells is believed to be regulated primarily by cyclin dependent kinases CDK2, CDK3 and CDK4 (and possibly also CDK6 in some cells) in association with at least cyclins D and E, the complexes of CDK2 and CDK4 (and possibly CDK6) with D type cyclins in particular playing an important role in controlling progression through the G1 restriction point whilst the CDK2/cyclin E complexes are essential for bringing about the transition from G1 into S phase. Once S phase is entered it is believed that further progression and entry into G2 then requires activated complexes of CDK2 with another cyclin which is designated cyclin A, i.e. complexes CDK2/cyclin A. Finally, for the transition from G2 phase to M phase and initiation of mitosis, activated complexes of the cyclin dependent kinase designated CDK1 (also known as Cdc2) with a cyclin designated cyclin B (and also complexes of CDK1 with cyclin A) are required.

In general, control of the cell cycle and activity of CDK's involves a series of stimulatory and inhibitory phosphorylation and dephosphorylation reactions, and in exercising their regulatory functions the CDK/cyclin

complexes when activated use ATP as a substrate to phosphorylate a variety of other substrate cell proteins, usually on serine and threonine groups thereof. Control of the cell cycle may also involve inhibitors of CDK/cyclin complexes which block the catalytic function of these enzymes so as to lead to arrest of the cell cycle. Certain natural inhibitors, such as for example the inhibitory proteins known as p16 and p21, can block cell cycle progression by binding selectively to CDK/cyclin complexes to inactivate the latter.

Control by inhibitors of CDK function may therefore provide a further mechanism for controlling cell cycle progression, and this has led to proposals for using CDK inhibitors as antiproliferative therapeutic agents, in antitumour therapy for example, for targeting abnormally proliferating cells and bringing about an arrest in cell cycle progression. This has seemed to be especially appropriate since it is known that severe disorders or irregularities in cell cycle progression frequently occur in human tumour cells, often accompanied by over-expression of CDK's and other proteins associated therewith. Also, compared to established cytotoxic antitumour drugs, the use of inhibitors of cell proliferation acting through CDK's would have the advantage of avoiding a direct interaction with DNA, thereby giving a reduced risk of secondary tumour development.

The potential therapeutic applications and other possible uses have accordingly led to a search for further chemical inhibitors of CDK's, especially selective inhibitors that may be suitable for pharmaceutical use. Inhibitory activity and selectivity of selected CDK/cyclin complexes is generally assayed by measuring the kinase activity in phosphorylating the protein histone H1 (one of the major protein constituents of chromatin which generally provides a good CDK substrate) in the presence of the suspected inhibitor under test. A number of compounds having potentially useful CDK inhibitory properties that have been identified in this way are described in a review article, of which the content is incorporated herein by reference, entitled "Chemical inhibitors of cyclin-dependent kinases" by Laurent Meijer published in *Cell Biology* (Vol. 6), October 1996. Among the compounds referred to in the above-mentioned article is a potent CDK1 and CDK2 inhibiting adenine derivative 2-(2-hydroxyethylamino)-6-benzylamino-9-methyl-purine, named "olomoucine", and also a close analogue incorporating modifications at positions 2, 6 and 9, namely, 6-(benzylamino)-2(R)-[1-(hydroxymethyl)propyl]amino]-9-isopropylpurine. This latter compound is named "roscovitine" and is even more potent than olomoucine as a CDK inhibitor. The strong but selective CDK inhibitory properties of olomoucine were first described in a paper by J. Vesely et al entitled "Inhibition of cyclin-dependent kinases by purine analogues", *Eur. J. Biochem.* 224, 771-786 (1994), and

further studies on CDK inhibitory properties of a range of purine compounds in the form of adenine derivatives, including olomoucine and roscovitine, are reported and discussed in a paper by L. Havlicek et al entitled  
5 "Cytokinin-Derived Cyclin-Dependent Kinase Inhibitors: Synthesis and cdc2 Inhibitory Activity of Olomoucine and Related Compounds" *J. Med. Chem.* (1997) 40, 408-412. Again, the content of these publications is to be regarded as being incorporated herein by reference.

10 The inhibitory activity of both olomoucine and roscovitine has been shown to result from these compounds acting as competitive inhibitors for ATP binding. It may be noted that olomoucine at least is reported as having a total lack of inhibitory activity in relation to many  
15 common kinases other than CDK's. Selectivity is further manifest by the fact that both olomoucine and roscovitine inhibit activity of CDK1, CDK2 and CDK5, but neither has been found to be active against CDK4 or CDK6.

Olomoucine in particular has been regarded as  
20 providing a lead compound for helping to identify and design further purine based CDK inhibitors, and based on structure/activity studies it was suggested in the above-mentioned paper of Vesely et al that N9 substitution by a hydrophobic residue such as methyl, 2-hydroxyethyl or  
25 isopropyl was important, e.g. to provide a direct hydrophobic interaction with the CDK, and that a side chain at C2 appeared to be essential. Similarly, in the paper of Havlicek et al, apart from observing that for

purine compounds to have CDK inhibitory activity the 1 and 7 positions, and possibly the 3 position, of the purine ring must remain free to permit hydrogen bonding, it was also stated that a polar side chain at position 2 appears to be essential and that N9 substitution by a hydrophobic residue is also probably important for positive binding. Positions 2, 6 and 9 in the purine ring were identified as being the positions which control binding to CDK1.

10 In the review article of Meijer, it is also mentioned that as a result of crystallization of CDK-inhibitor complexes, and in particular co-crystallization studies with CDK2, it has been found that inhibitors such as olomoucine and roscovitine localize in the ATP binding  
15 pocket which is located in the cleft between the small and large lobes of the CDK protein molecule, and that specificity was probably provided by portions of the inhibitor molecules interacting with the kinases outside the ATP binding sites.

## 20 Summary of the Invention

The present invention has developed from an observation made in the course of testing various guanine derivatives for activity as inhibitors of the DNA repair protein O<sup>6</sup>-methylguanine DNA-methyltransferase (MGMT) when  
25 it was found unexpectedly that although the compound O<sup>6</sup>-cyclohexylmethylguanine had very little activity as a MGMT inhibitor, it was nonetheless cytotoxic and showed



very high inhibitory activity, comparable to that of olomoucine, against CDK1(cdc2)/cyclin B complexes. This was particularly surprising against the background discussed above in relation to olomoucine given that this  
5 guanine compound has no substituents at either the 2-NH<sub>2</sub> position or the 9 position in the purine ring and that the replacement of the 6-NH by 6-O made the compound less like ATP with which olomoucine at least is believed to compete for binding sites.

10 Subsequently, other guanine derivatives have been identified, more closely related to O<sup>6</sup>-cyclohexylmethylguanine than to compounds such as olomoucine and roscovitine, which show significant CDK inhibitory activity, and crystallographic studies have revealed that  
15 complexes of CDK2 (homologous with CDK1, at least in respect of the catalytic binding site) with guanine derivatives such as O<sup>6</sup>-cyclohexylmethylguanine and O<sup>6</sup>-cyclohex-1-enylmethylguanine bind together in a different manner from complexes of CDK2 with olomoucine.

20 This is illustrated in the accompanying drawings in which:

FIGURE 1 is a diagram indicating the manner in which olomoucine binds to CDK2;

FIGURE 2 is a similar diagram indicating the manner in  
25 which the compound O<sup>6</sup>-cyclohexylmethylguanine has been found to bind to CDK2;

FIGURE 3 is a diagram representing a crystal structure showing the manner in which the R enantiomeric form of the compound  $O^6$ -(2,2-dimethyl-1,3-dioxolane-4-methoxy)-guanine has been found to bind to CDK2.

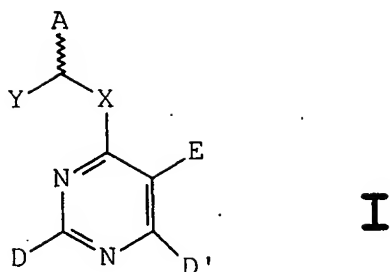
5           Whereas with olomoucine it is the polar side chain on N2 of the purine ring that seats within the ATP ribose binding pocket of the CDK2 protein, and the N9 methyl substituent engages a separate hydrophobic specificity pocket, with N7 and 6-NH being involved in hydrogen  
10 bonding to the protein, in the binding mode illustrated in FIGURE 2 it is the cycloalkyl ring of the substituent at the 6-position that seats in the ATP ribose binding pocket while hydrogen bond links are formed to N9, N3 and 2-NH. In other words, the orientation as compared with  
15 the binding of olomoucine is completely reversed. A similar situation obtains with the binding mode illustrated in FIGURE 3 where the involvement of some water molecules is also indicated.

          It will accordingly be clear that conclusions  
20 reached in respect of structure/activity relationships in the adenine series of compounds exemplified by olomoucine and roscovitine are likely no longer to be valid for all purine derivatives, especially guanine derivatives, and as disclosed in our co-pending International Patent  
25 Application No. PCT/GB98/02025 a range of other purine compounds has been identified which have inhibitory activity in respect of at least some CDK's and which are believed to bind in the manner shown in Figure 2 (or

Figure 3) rather than in the manner shown in Figure 1.

It has now been found that there are also a number of single ring nitrogen-containing heterocyclic compounds, especially pyrimidine compounds, which when provided with suitable substituents can act like or mimic the above-mentioned purine compounds and exhibit inhibiting activity in respect of at least some CDK proteins. Like the purine compounds, for CDK inhibiting activity these pyrimidine compounds will be linked in the 4-position through a side chain to an optionally substituted 4- to 8-membered carbocyclic or heterocyclic ring which, it is believed, will seat in the ATP ribose binding pocket of the CDK protein. Also, there will usually be an amino or partially-substituted amino group at the 6-position which will interact with a hydrophobic specificity pocket of the CDK protein in a manner analogous to that shown in Figure 2 or Figure 3 for the binding of a CDK inhibiting purine. Preferably, there will also be an amino or substituted amino group at position 2.

More particularly, in one aspect the present invention provides pharmaceutical compositions for treatment of cell proliferation disorders in mammals, for example tumours, said compositions containing as the active ingredient a CDK-inhibiting pyrimidine compound having the structural formula I below:



in which, in preferred embodiments,

X is O, S or  $\text{CHR}_x$

where  $R_x$  is H or  $\text{C}_{1-4}$  alkyl;

D is H or  $\text{NZ}_1\text{Z}_2$

5 where  $Z_1$  and  $Z_2$  are each independently H,  $\text{C}_{1-4}$  alkyl,  $\text{C}_{1-4}$  hydroxyalkyl, optionally substituted aryl or optionally-substituted aralkyl;

A is selected from H,  $\text{C}_{1-4}$  alkyl,  $\text{C}_{1-4}$  alkoxy, hydroxy,  $\text{CH}_2(\text{CH}_2)_n\text{OH}$  ( $n=1-4$ ), and  $\text{NR}_{a1}\text{R}_{a2}$  where  
10  $\text{R}_{a1}$  and  $\text{R}_{a2}$  are each independently H or  $\text{C}_{1-4}$  alkyl;

Y is or includes an optionally substituted 4- to 8-membered carbocyclic or heterocyclic ring;

D' is H or  $\text{NZ}_3\text{Z}_4$

15 where  $Z_3$  and  $Z_4$  are each independently H,  $\text{C}_{1-4}$  alkyl,  $\text{C}_{1-4}$  hydroxyalkyl, optionally substituted aryl or optionally-substituted aralkyl;

E is selected from H, NO,  $\text{NO}_2$ ,  $\text{N}=\text{N}-\text{Ar}$  where Ar is an optionally substituted aryl or optionally substituted aralkyl,  $\text{NR}_{e1}\text{R}_{e2}$  or  $\text{NR}_{e1}\text{NR}_{e2}\text{R}_{e3}$  ( $\text{R}_{e1}$ ,  
20  $\text{R}_{e2}$  and  $\text{R}_{e3}$  each being independently H,  $\text{C}_{1-4}$  alkyl,  $\text{C}_{1-4}$  hydroxyalkyl, an optionally substituted aryl or an optionally substituted

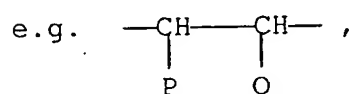
aralkyl),  $C(R_e)=U$  ( $R_e$  being hydrogen,  $C_{1-4}$  alkyl or substituted alkyl, e.g. hydroxyalkyl, or an unsubstituted or substituted aryl or aralkyl, e.g. benzyl, and  $U$  being selected from  $O$ ,  $NR_e'$ ,  $NOR_e'$  and  $N-NR_e'R_e''$  where  $R_e'$  and  $R_e''$  are each independently  $H$ ,  $C_{1-4}$  alkyl or  $CONH_2$ ),  $T$ ,  $CH_2T$ ,  $CHT_2$  and  $CT_3$ , where  $T$  is a halide  $I$ ,  $Br$ ,  $Cl$  or  $F$ .

Certain of the compounds within the scope of the above definition are already known per se, but have not been previously known in a capacity as CDK inhibitors. Some of these compounds are believed to be new chemical entities. Moreover, in some cases the CDK inhibitory activity has been found to have a selectivity towards different CDK's which is notably different from that of olomoucine. Thus, the present invention has in effect identified a further class of CDK inhibitors and has considerably enlarged the range of compounds available for use as CDK inhibitors.

So long as it is able to fit or seat in the ATP ribose binding pocket of a CDK protein and permit binding in the general manner depicted in Figure 2 rather than Figure 1, there is a wide range of substituents likely to be suitable for  $Y$ . In some cases it may be helpful for  $Y$  to comprise a ring structure that includes polar hydroxyl substituents or the like.

In most embodiments  $Y$  will be a cycloalkane or

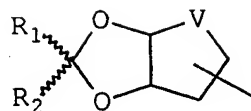
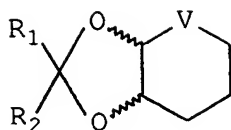
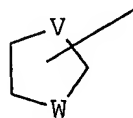
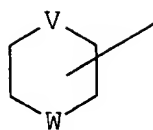
cycloalkene ring, preferably a 5- or 6- membered ring having up to two double bonds. One or two carbon atoms in the ring may be replaced, however, by hetero atoms or groups, particularly O, S, NR' (where R' is H or C<sub>1-4</sub> alkyl) or, in a cycloalkene ring, -N=. Where the ring is substituted the substituent or each substituent (at any position) will preferably be selected from H, C<sub>1-4</sub> alkyl, OH, C<sub>1-4</sub> alkoxy, halogen, CF<sub>3</sub>, CN, N<sub>3</sub> and NR<sub>Y1</sub>R<sub>Y2</sub> where R<sub>Y1</sub> and R<sub>Y2</sub> are each independently H or C<sub>1-4</sub> alkyl. Moreover, in the case where there are two substituents on adjacent atoms of the ring,



these substituents P and Q may be linked to form an additional fused ring structure, e.g. a 4-, 5- or 6-membered carbocyclic or heterocyclic ring. This additional ring structure may include for example up to two hetero atoms or groups such as O, S or NH, and it may also be substituted by one or more substituents, e.g. a C<sub>1-4</sub> alkyl group or groups or a phenyl or substituted phenyl group. In some embodiments, Y may also be adamantyl.

Examples of ring structures represented by Y include

13



where V and W are each selected independently from

O, S, NR' (R' is H or C<sub>1-4</sub> alkyl)

and CH<sub>2</sub> (or =CH-); and

5 R<sub>1</sub> and R<sub>2</sub> are each H or C<sub>1-4</sub> alkyl.

As indicated above, these ring structure can optionally bear substituents which may be the same or different and which may *inter alia* be selected from H, C<sub>1-4</sub> alkyl, C<sub>1-4</sub> alkoxy, -OH, NR<sub>Y1</sub>R<sub>Y2</sub> (where R<sub>Y1</sub> and R<sub>Y2</sub> are  
 10 each independently H or C<sub>1-4</sub> alkyl), CF<sub>3</sub>, halogen, N<sub>3</sub>, CN, optionally substituted aryl (e.g. phenyl), and optionally substituted aralkyl (e.g. benzyl). Also, as already indicated, it may be useful in some cases for the ring structure to include a plurality of polar substituents  
 15 such as hydroxyl for example.

In general, the pharmaceutical compositions of this invention will contain an effective CDK-inhibiting non-toxic amount of the active pyrimidine compound, and will be formulated in accordance with any of the methods well

known in the art of pharmacy for administration in any convenient manner. The compounds may for example be presented in unit dosage form admixed with at least one other ingredient providing a compatible pharmaceutically acceptable additive, carrier, diluent or excipient.

It will be understood that where reference is made in this specification to compounds of formula I such reference should be construed as extending also to their pharmaceutically acceptable salts and to other pharmaceutically acceptable bioprecursors (pro-drug forms) where relevant. The term "pro-drug" is used in the present specification to denote modified forms or derivatives of a pharmacologically active compound which biodegrade *in vivo* and become converted into said active compound after administration, especially oral or intravenous administration, in the course of therapeutic treatment of a mammal. Such pro-drugs are commonly chosen because of an enhanced solubility in aqueous media which helps to overcome formulation problems, and also in some cases to give a relatively slow or controlled release of the active agent.

It should also be understood that where any of the compounds referred to can exist in more than one enantiomeric and/or diastereoisomeric form, all such forms, mixtures thereof, and their preparation and uses are within the scope of the invention. It should be noted, however, that stereochemical considerations are likely to be important and there may be considerable selectivity



such that different enantiomers or diastereoisomers have significantly different inhibitory activity.

The invention also includes of course the use of the CDK inhibiting compounds referred to for the manufacture of medicaments or pharmaceutical compositions as referred to above, and it also includes the treatment of abnormal cellular proliferation disorders using such medicaments or pharmaceutical compositions. It further includes some pyrimidine compounds which are new chemical entities useful as intermediates in the synthesis of said CDK inhibiting compounds.

Preferably, in compounds in accordance with structural formula I used in carrying out the invention, D will be an unsubstituted amino group  $-NH_2$ , and X will be oxygen.

Although it will usually be preferred that Y should comprise a saturated or partially saturated carbocyclic or heterocyclic ring structure, it should be recognised that in some cases Y may comprise an aromatic ring system (e.g. optionally substituted aryl or aralkyl), and still provide compounds of interest as potentially selective CDK inhibitors that may be useful in the context of the present invention, especially insofar as they may be structured so as to bind with CDK's in substantially the same manner as depicted in Figure 2.

Although a number of the CDK inhibitor compounds

herein disclosed are already known per se, as previously pointed out some of the compounds are believed to be novel and to constitute new chemical entities.

Examples of compounds which are at present  
5 especially preferred for use in carrying out the invention, either directly or as intermediate compounds, and which include the most potent CDK inhibitors that have been identified, at least when assayed in vitro against CDK1 and/or CDK2, include the following:

2,6-Diamino-4-cyclohexylmethoxy-5-nitroso  
pyrimidine;  
2,5,6-Triamino-4-cyclohexylmethoxy-pyrimidine;  
2,6-Diamino-5-(4'-Chlorophenyl)azo-4-cyclohexyl  
methoxypyrimidine;  
2,6-Diamino-4-benzyloxypyrimidine;  
2,6-Diamino-4-benzyloxy-5-nitrosopyrimidine;  
2,5,6-Triamino-4-Benzyloxypyrimidine;  
2,6-Diamino-4-cyclohex-3-enylmethoxy-pyrimidine;  
2,6-Diamino-4-cyclohex-3-enylmethoxy-5-nitroso  
pyrimidine;  
2-Amino-4-cyclohexylmethoxy-6-methylamino  
pyrimidine;  
2-Amino-6-benzylamino-4-cyclohexylmethoxy  
pyrimidine; and  
2,6-Diamino-4-cyclohexyl-methoxy-pyrimidine-5-  
carbaldehyde.

## 10 Biological Activity

Assays are available for testing the inhibitory

activity of the compounds of interest against a range of CDK/cyclin complexes, including CDK1/cyclin A, CDK1/cyclin B, CDK1/cyclin F, CDK2/cyclin A, CDK2/cyclin E, CDK4/cyclin D, CDK5/35 and CDK6/cyclin D3, and it is of particular interest to note the selectivity of some of the compounds against different CDK's.

Test results showing CDK inhibitory activity values measured for some of the compounds that have been prepared are shown in Table 1 at the end of the present description. Where the compounds exist in different enantiomeric forms, the assays have generally been carried out on racemic mixtures. Apart from reference compounds, the compounds listed are accompanied by an NU reference or identification code number. Table 1 includes the compounds which at present are the most preferred of those that have been prepared, although as yet not all have been fully tested.

In general, the studies carried out fully support the belief that CDK inhibitory characteristics of compounds tested reflect an ability of these compounds to act as effective antitumour drugs.

The inhibition assays have been carried out using methods based on those described in the paper hereinbefore referred to of J. Vesely et al and in the paper of L. Azzi et al (1992) *Eur. J. Biochem.* 203, 353-360. By way of example, however, a typical protocol is summarised below.

**CDK Assay Example***Reagents:*

Buffer C (containing 60mM b-glycerophosphate, 30mM nitrophenyl phosphate, 25mM MOPS pH 7.0, 5mM EGTA, 15mM MgCl<sub>2</sub>, 1mM MgCl<sub>2</sub> and 0.1mM sodium orthovanadate) is made up as follows:

	FW	g/100ml	Final conc
b-glycerophosphate (RT)	216	1.3	60mM
MOPS (RT)	209.3	0.52	25mM
10 EGTA (RT)	380.4	0.19	5mM
MgCl <sub>2</sub> (RT)	203.4	0.305	15mM

First dissolve above ingredients in about 80ml distilled water and pH to 7.0

Then add 1ml 10mM sodium orthovanadate  
 15 (1.84mg/ml - FW = 183.9 RT)  
 final conc = 0.1mM

cool to 4°C

Then Add

	4-nitrophenyl phosphate (-20°C)	279.2	1.112	30mM
20	DTT (4°C)	154.2	.0154	1mM

(Alternatively, make up 100mM DTT (15.4mg/ml) and store in 1.2ml aliquots in freezer, thaw and add 1ml to buffer, above)

Make up to 100ml and store in 5ml aliquots in freezer

25 Affinity purified p34 cdc2(CDK1)/cyclinB from M-phase starfish (*Marthasterias glacialis*) in 20% glycerol is stored at -80°C in chest freezer

100mM Olomoucine (Cat # LC-0-3590-M025 Alexis Co. Bingham

Nottingham). FW = 298.35 29.835mg/ml = 100mM, 25ml aliquots stored in freezer.

1% phosphoric acid (58.8ml 85% phosphoric acid + 4.942 litres water)

5 *Make up the following on day of assay:*

Histone H1 (type III-S (Sigma) 4° C) 5mg/ml in buffer C.

[<sup>32</sup>P]ATP 75mM: Make up using (multiples of) the following proportions:

2ml [<sup>32</sup>P]ATP (3000Ci/mMol PB168 Amersham, stored in  
10 radioactive freezer) + 7.5ml 1mM cold ATP (-20°C)  
(0.551mg/ml - 200ml aliquots stored in freezer) +  
90.5ml buffer C

Conc. = 12.5 mM in final assay

*Assay Procedure*

15 DMSO cannot exceed 1% in the assay mixture. Inhibitors  
are added at 1/10 final assay volume and 10x final  
strength. DMSO stocks must therefore be diluted to 10x  
final desired concentration in ≤ 10% DMSO, ≥ 90% buffer  
C. Suggested concentration ranges = 0, 1, 10, 100mM so  
20 DMSO stocks of 0, 100, 1,000 and 10,000mM are diluted  
1/10 in buffer C before adding to assay.

*Preparation:*

Label set of 0.2ml microtubes for assay (e.g. A<sub>0</sub>, A<sub>1</sub>, A<sub>10</sub>,  
A<sub>100</sub>) in suitable rack and another set of eppendorfs for

drug dilution

Label phosphocellulose filters in pencil (e.g. A<sub>0</sub>, A<sub>1</sub>, A<sub>10</sub>, A<sub>100</sub>) and fold longitudinally to make a "pitched roof"

Set up water bath at 30°C containing second rack for  
5 microtubes

Set up beaker containing wire mesh insert and magnetic flea below mesh insert, together with 400ml 1% phosphoric acid, on magnetic stirrer

*Reaction mix:*

10 All reagents (except DMSO stocks) should be kept on ice until assay initiated.

Place rack of assay tubes on ice

In each tube put:

16 ml buffer C  
15 1ml cdc2/cyclinB kinase  
5 ml histone H1  
3 ml inhibitor

Start reaction in each tube at 30 second intervals by adding

20 5 ml [<sup>32</sup>P]ATP vortexing and placing in rack in waterbath at 30°C

Terminate reaction after 10 min at 30 second intervals in tubes in same order by removing

25 ml reaction mix and spotting onto appropriately  
25 labelled filter, allowing to dry for 20 - 30 seconds and

transferring to stirring 1% phosphoric acid.

Blank incubation is performed as above but without histone (add 5 ml buffer C instead) Washing blank is 5 ml ATP added directly to filter.

5 Wash filters 5-6 times 5 min each

Dry the filters on paper towel

Count in mini scintillation vials with 5ml scintillant.

3 x standards of 5 ml ATP counted also (375pmoles ATP)

NB. The assay can be simplified by making up stock  
10 reaction mix as follows:

(1 part cdc2/cyclinB, 16 parts buffer C, 5 parts histone H1)x Number of assay tubes +1 and add 22 ml to each assay tube containing 3 ml buffer C  $\pm$  inhibitor. It is still necessary, however, to make up assay blank (i.e. without  
15 histone) separately.

#### DESCRIPTION OF ILLUSTRATIVE EXAMPLES

The following examples and description of stages in synthetic routes of preparation of various exemplary compounds of interest serve further to illustrate the  
20 present invention, but should not be construed in any way as a limitation thereof. Again, in many instances the compounds described are accompanied by an NU reference or identification code number.

**2,6-Diamino-4-cyclohexylmethoxypyrimidine (NU6034)**

25 **(for use as an intermediate compound)**

Cyclohexylmethanol (30 ml) and sodium (0.76 g, 32 mmol) were heated together under N<sub>2</sub> at 150 °C for 1.5 h. 4-Chloro-2,6-diaminopyrimidine (4.32 g, 30 mmol) was added and the reaction mixture was heated under reflux for 2 h at 180 °C under N<sub>2</sub>. The solvent was removed under vacuum at the oil pump using a short path distillation apparatus. The resulting residue was purified by column chromatography, using 10% methanol in dichloromethane as the eluent. The final product was further purified by recrystallisation from methanol (4.69 g, 70%), m.p. 142 °C; (Found: C, 59.35; H, 8.21; N, 25.17% C<sub>11</sub>H<sub>18</sub>N<sub>4</sub>O requires C, 59.45; H, 8.11; N, 25.23%);  $\delta_H$  (200 MHz, d<sub>6</sub>-DMSO) 1.03-1.37 (5H, m, C<sub>6</sub>H<sub>11</sub>), 1.79-1.84 (6H, m, C<sub>6</sub>H<sub>11</sub>), 4.00 (2H, d, OCH<sub>2</sub>,  $J = 6.3$  Hz), 5.13 (1H, s, C(5)H), 5.96 (2H, br s, NH<sub>2</sub>), 6.10 (2H, br s, NH<sub>2</sub>);  $m/z$  (+EI) 222 (M<sup>+</sup>, 29%), 139 (M<sup>+</sup>-C<sub>6</sub>H<sub>11</sub>, 42), 126 (MH<sup>+</sup>-C<sub>7</sub>H<sub>13</sub>, 100), 110 (MH<sup>+</sup>-C<sub>7</sub>H<sub>13</sub>O, 28), 98 (82).

**2,6-Diamino-4-cyclohexylmethoxy-5-nitrosopyrimidine  
(NU6027)**

2,6-Diamino-4-cyclohexylmethoxypyrimidine (0.28 g, 1.26 mmol) was dissolved in warm glacial acetic acid solution (30%, 10 ml). The solution was heated to 80 °C and sodium nitrite solution (0.12 g, 1.72 mmol in 5 ml of H<sub>2</sub>O) was added dropwise over 1 h, until an excess of oxidant, as indicated by starch iodide paper, was observed. The reaction mixture was allowed to cool to room temperature and the violet crystals were collected by filtration, and washed well with water. The title



compound was purified by recrystallisation from ethanol (0.26 g, 83%), m.p. 254 °C; (Found: C, 52.73; H, 6.59; N, 27.56%  $C_{11}H_{17}N_5O_2$  requires C, 52.59; H, 6.77; N, 27.89%);  $\delta_H$  (200 MHz,  $d_6$ -DMSO) 1.09-1.38 (5H, m,  $C_6H_{11}$ ), 1.73-2.00 (6H, m,  $C_6H_{11}$ ), 4.39 (2H, d,  $OCH_2$ ,  $J = 6.3$  Hz), 7.86 (2H, br s,  $NH_2$ ), 8.08 (1H, br s, NH), 10.19 (1H, br s, NH);  $m/z$  (+EI) 251 ( $M^+$ , 25%), 155 ( $M^+ - C_7H_{13}$ , 100), 138 ( $M^+ - C_7H_{13}O$ , 72), 81 (9).

**2,5,6-Triamino-4-cyclohexylmethyloxypyrimidine (NU6035)**

10 To a stirred suspension of 2,6-diamino-5-nitroso-4-cyclohexylmethoxypyrimidine (0.10 g, 0.4 mmol) in water (5 ml) at 50 °C was added sodium dithionite (0.16 g, 0.92 mmol) in portions over a period of 5 h. The reaction mixture was allowed to cool to room temperature and stirred at ambient temperature overnight. The pH of the solution was adjusted to 7 with aqueous ammonia solution (2 ml), and the resulting fine yellow precipitate was collected by filtration and washed with water. The product was purified by recrystallisation from water  
20 (0.06 g, 60%), m.p. 154 °C; (Found: C, 55.50; H, 7.95; N, 29.34%  $C_{11}H_{19}N_5O$  requires C, 55.69; H, 8.02; N, 29.53%);  $\delta_H$  (200 MHz,  $d_6$ -DMSO) 1.02-1.39 (5H, m,  $C_6H_{11}$ ), 1.71-1.89 (6H, m,  $C_6H_{11}$ ), 3.22 (2H, br s,  $NH_2$ ), 4.03 (2H, d,  $OCH_2$ ,  $J = 6.53$  Hz), 5.32 (2H, br s,  $NH_2$ ), 5.71 (2H, br s,  $NH_2$ );  $m/z$  (+EI) 237 ( $M^+$ , 84%), 155 ( $MH^+ - C_7H_{13}$ , 100), 124 ( $MH^+ - C_7H_{13}O$ ,  
25 15).

**4-Chlorobenzenediazonium tetrafluoroborate**

**(for use as an intermediate compound)**

4-Chloroaniline (1.0 g, 7.87 mmol) was suspended in 6 M HCl (4 ml), and the stirred reaction mixture was cooled to 0 °C. A solution of sodium nitrite (0.54 g, 7.87 mmol) in water (1 ml) was added dropwise over 5 minutes, and the mixture was stirred at 0 °C for a further 20 minutes. Ice cold fluoroboric acid (40%, 1.14 ml, 18.11 mmol) was added in a single portion, and the mixture was allowed to warm to room temperature over 12 h. After cooling in an ice bath, the resulting precipitate was collected by filtration, and washed sequentially with water, methanol and diethyl ether. The compound was purified by precipitation from cold acetone;  $\delta_H$  (200 MHz,  $d_6$ -DMSO) 8.24 (2H, dd), 8.810 (2H, dd).

**2,6-Diamino-5-(4'-Chlorophenyl)azo-4-cyclohexylmethoxypyrimidine (NU6037)**

To a stirred solution of 4-chlorobenzenediazonium tetrafluoroborate (0.09 g, 0.68 mmol) in dry DMF (5 ml) under  $N_2$  at 0 °C, was added 2,6-diamino-4-cyclohexylmethoxypyrimidine (0.15 g, 0.68 mmol), and the stirred reaction mixture was allowed to warm to ambient temperature over 72 h. The solvent was removed under reduced pressure, and the residue was triturated with water, and filtered. The desired product was obtained after recrystallisation from methanol (0.094 g, 39%);  $\delta_H$  (200 MHz,  $d_6$ -DMSO) 1.14-1.47 (5H, m,  $C_6H_{11}$ ), 1.81-1.95 (6H, m,  $C_6H_{11}$ ), 4.31 (2H, d,  $OCH_2$ ,  $J = 6.04$  Hz), 7.36 (2H, br s,

NH<sub>2</sub>), 7.62 (2H, d, Ar C(3)H and Ar C(5)H, J = 8.7 Hz), 7.85 (2H, d, Ar C(2)H and Ar C(6)H, J = 8.72 Hz), 8.04 (1H, br s, NH).

**2,6-Diamino-4-benzyloxypyrimidine (NU6038)**

5 Sodium (0.41 g, 17.8 mmol) was added to benzyl alcohol (15 ml) under a nitrogen atmosphere and the mixture was heated at 150 °C for 1.5 h. 2,6-Diamino-4-chloropyrimidine (2.16 g, 14.94 mmol) was added and the reaction mixture was stirred at 180 °C for a further 2 h.

10 Volatiles were removed in vacuo and the resulting residue was chromatographed on silica with dichloromethane: methanol (9:1) as eluent, to yield the title product as a white solid (1.98 g, 62%);  $\nu_{\max}/\text{cm}^{-1}$  3347 (NH), 1498 (C<sub>6</sub>H<sub>5</sub>), 1608 (C<sub>6</sub>H<sub>5</sub>);  $\delta_{\text{H}}$  (200 MHz, d<sub>6</sub>-DMSO) 5.20 (1H, s, C(5)H),

15 5.32 (2H, s, OCH<sub>2</sub>), 6.05 (2H, br s, NH<sub>2</sub>), 6.17 (2H, br s, NH<sub>2</sub>), 7.41-7.48 (5H, m, C<sub>6</sub>H<sub>5</sub>);  $m/z$  (+EI) 216 (M<sup>+</sup>, 100%), 139 (M<sup>+</sup>-C<sub>6</sub>H<sub>5</sub>, 33), 91 (94).

**2,6-Diamino-4-benzyloxy-5-nitrosopyrimidine (NU6039)**

2,6-Diamino-4-benzyloxypyrimidine (0.5 g, 2.3 mmol)

20 was dissolved in warm acetic acid (30%, 10 ml) and the reaction mixture was heated to 80 °C. A solution of sodium nitrite (0.22 g, 3.19 mmol) in water (5 ml) was added dropwise over 1 h, when an excess of oxidant was evident by starch-iodide paper. The reaction mixture was

25 allowed to cool to room temperature, and the violet crystals which deposited were collected and washed with water (0.53 g, 98%), m.p. decomposed 209 °C; (Found: C,

55.32; H, 5.28; N, 26.47%  $C_{11}H_{11}N_5O_2 \cdot 0.1 H_2O$  C, 55.98; H, 4.75; N, 29.69%);  $\nu_{max}/cm^{-1}$  3408 (NH), 2952 (CH<sub>2</sub>), 1610 (C<sub>6</sub>H<sub>5</sub>), 1518 (NO);  $\delta_H$  (200 MHz, d<sub>6</sub>-DMSO) 5.69 (2H, s, OCH<sub>2</sub>), 7.44-7.68 (5H, m, C<sub>6</sub>H<sub>5</sub>), 8.0 (2H, d, NH<sub>2</sub>), 8.17 (1H, s, NH), 10.19 (1H, s, NH);  $m/z$  (+EI) 245 (M<sup>+</sup>, 25%), 91 (100), 65 (9).

#### 2,5,6-Triamino-4-Benzyloxypyrimidine (NU6040)

To a suspension of 2,6-diamino-4-benzyloxy-5-nitrosopyrimidine (0.3 g, 1.28 mmol) in water (10 ml) at 10 50 °C was added sodium dithionite (0.48 g, 2.76 mmol) in portions over 5 h. The reaction mixture was stirred at room temperature overnight, heated again to 50 °C and a further quantity of sodium dithionite (0.4 g) was added. After stirring for a further 12 h, the reaction mixture 15 was cooled to room temperature, and the solution was adjusted to pH 7 with aqueous ammonia solution (0.2 ml). The resultant fine yellow solid which deposited was collected, washed with water and recrystallised from hot water (0.11 g, 35%), m.p. 130-135 °C;  $\nu_{max}/cm^{-1}$  3394 (NH<sub>2</sub>), 20 3033 (C<sub>6</sub>H<sub>5</sub>);  $\delta_H$  (200 MHz, d<sub>6</sub>-DMSO) 5.36 (2H, s, OCH<sub>2</sub>), 5.40 (2H, s, NH<sub>2</sub>), 5.81 (2H, s, NH<sub>2</sub>), 7.39-7.56 (5H, m, C<sub>6</sub>H<sub>5</sub>).

#### 2,6-Diamino-4-cyclohex-3-enylmethyloxypyrimidine (NU6046)

To a stirred solution of sodium (0.4 g, 17.4 mmol) in 1,2,3,6-Tetrahydrobenzyl alcohol (20 ml, 0.17 mol) 25 under nitrogen at 120 °C, was added 2,6-diamino-4-chloropyrimidine (2 g, 13.84 mmol) and the reaction mixture was stirred for a further 2 h at 180 °C. The

solvents were removed *in vacuo* and the crude product was purified by chromatography on silica, employing dichloromethane:methanol (9:1) as eluent. Recrystallisation from ethyl acetate-petrol gave the  
5 title compound as a yellow solid (1.3 g, 43%), m.p. 89 °C;  $\delta_H$  (200 MHz,  $d_6$ -DMSO) 1.26-2.24 (7H, m,  $C_6H_7$ ), 4.16 (2H, d,  $OCH_2$ ,  $J = 6.56$  Hz), 5.14 (1H, s, C(5)H), 5.76 (2H, s,  $C_2H_2$ ), 5.96 (2H, br s,  $NH_2$ ), 6.10 (2H, br s,  $NH_2$ );  $m/z$  (+EI) 220 ( $M^+$ , 27%), 125 ( $MH^+ - C_7H_{11}$ , 97), 98 (25).

10 **2,6-Diamino-4-cyclohex-3-enylmethyloxy-5-nitrosopyrimidine (NU6045)**

A solution of 2,6-diamino-4-cyclohex-3-enylmethyloxypyrimidine (0.5 g, 2.27 mmol) in 30% acetic acid solution was heated to 80 °C, and sodium nitrite  
15 solution (0.22 g, 3.19 mmol, in 10 ml  $H_2O$ ) was added dropwise over 1h until excess oxidant was in evidence (starch-iodide paper). The reaction mixture was cooled to room temperature and the resultant violet crystals were collected, washed thoroughly with water and dried  
20 (0.52 g, 92%), m.p. 237 °C;  $\delta_H$  (200 MHz,  $d_6$ -DMSO) 1.51-2.19 (7H, m,  $C_6H_7$ ), 4.51 (2H, d,  $OCH_2$ ,  $J = 5.66$  Hz), 5.82 (2H, br s,  $C_2H_2$ ), 7.95 (2H, br s,  $NH_2$ ), 8.15 (1H, br s, NH), 10.21 (1H, br s, NH);  $m/z$  (+EI) 249 ( $M^+$ , 22%), 155 ( $M^+ - C_7H_{11}$ , 60), 138 ( $M^+ - C_7H_{11}O$ , 100), 69 (24).

25 **2-Amino-4-chloro-6-methylaminopyrimidine (NU6042)**  
(for use as an intermediate compound)

A mixture of 2-amino-4,6-dichloropyrimidine (1 g, 6.1 mmol), methylamine (0.8 ml), potassium carbonate (0.5 g, 3.62 mmol) and anhydrous ethanol (15 ml) were heated under reflux, under nitrogen, for 18 h. The reaction mixture was cooled to room temperature, filtered, and the filtrate was concentrated to a volume of approximately 2 ml, when a cream solid was obtained (0.82 g, 85%), m.p. 152-157 °C;  $\nu_{\max}/\text{cm}^{-1}$  3442 (NH), 2934 (CH<sub>3</sub>), 2549 (NH<sub>2</sub>);  $\delta_{\text{H}}$  (200 MHz, d<sub>6</sub>-DMSO) 3.48 (3H, s, CH<sub>3</sub>), 5.84 (1H, s, C(5)H), 6.53 (2H, br s, NH<sub>2</sub>), 7.28 (1H, br s, NH);  $m/z$  (+EI) 158 (M<sup>+</sup>, 100%), 123 (M<sup>+</sup>-Cl, 9), 94 (18).

**2-Amino-4-cyclohexylmethyloxy-6-methylaminopyrimidine (NU6041)**

2-Amino-4-chloro-6-methylaminopyrimidine (0.5 g, 2.25 mmol) was added to a stirred solution of sodium (0.062 g, 2.69 mmol) in cyclohexylmethanol (10 ml) under N<sub>2</sub>, and the reaction mixture was heated at 180 °C for 12 h. Solvents were removed *in vacuo* and the crude product was purified by chromatography on silica, employing dichloromethane:methanol (9:1) as eluent, to give the title compound as a white solid (0.03 g, 6%), m.p. 128-129 °C;  $\nu_{\max}/\text{cm}^{-1}$  3452 (NH), 2851 (NCH<sub>3</sub>), 1583 (NH<sub>2</sub>), 1514 (NH);  $\delta_{\text{H}}$  (200 MHz, d<sub>6</sub>-DMSO) 1.04-1.31 (5H, m, C<sub>6</sub>H<sub>11</sub>), 2.78 (3H, d, NCH<sub>3</sub>,  $J$  = 4.67 Hz), 4.02 (2H, d, OCH<sub>2</sub>), 5.10 (1H, s, C(5)H), 6.00 (2H, br s, NH<sub>2</sub>), 6.52 (1H, br d, NH,  $J$  = 4.22 Hz);  $m/z$  (+EI) 236 (M<sup>+</sup>, 37%), 206 (MH<sup>+</sup>-NHMe, 31), 153 (M<sup>+</sup>-C<sub>6</sub>H<sub>11</sub>, 45), 140 (MH<sup>+</sup>-C<sub>6</sub>H<sub>11</sub>CH<sub>2</sub>O, 100).

**2-Amino-6-benzylamino-4-chloropyrimidine****(for use as an intermediate compound)**

A mixture of 2-amino-4,6-dichloropyrimidine (0.5 g, 3.05 mmol), benzylamine (0.35 ml, 3.2 mmol), potassium carbonate (0.25 g, 1.81 mmol) and ethanol (15 ml) were heated to reflux for 16 h. The reaction mixture was cooled to room temperature and the solvents were removed under reduced pressure. The residue was triturated with ethyl acetate and the white product was collected by filtration. Concentration of the ethyl acetate filtrate also afforded a second crop of product. The combined solids were dried to give the required pyrimidine (0.36 g, 50%), m.p. 136 °C;  $\delta_H$  (200 MHz,  $d_6$ -DMSO) 4.55 (2H, br s, OCH<sub>2</sub>), 5.87 (1H, br s, C(5)H), 6.54 (2H, br s, NH<sub>2</sub>), 7.35-7.41 (5H, m, C<sub>6</sub>H<sub>5</sub>), 7.72 (1H, m, NH);  $m/z$  (+EI) 234 ( $M^+$ , 85%), 106 (100), 91 (C<sub>6</sub>H<sub>5</sub>CH<sub>2</sub><sup>+</sup>, 51%).

**2-Amino-6-benzylamino-4-cyclohexylmethyloxypyrimidine**

To a stirred solution of sodium (0.025 g, 1.09 mmol) in cyclohexylmethanol (5 ml, 43 mmol) under nitrogen at 100 °C, was added 2-amino-6-benzylamino-4-chloropyrimidine (0.2 g, 0.86 mmol), and the mixture was stirred at 180 °C for 2 h. After removal of solvents, the residue was redissolved in methanol, filtered and the filtrate was evaporated to dryness. The crude product was purified by chromatography on silica, employing petrol: ethyl acetate (8:2) as eluent, to give the title product as a yellow solid (0.13 g, 49%);  $\delta_H$  (200 MHz,  $d_6$ -

DMSO) 0.96-1.15 (5H, m, C<sub>6</sub>H<sub>11</sub>), 1.23-1.34 (6H, m, C<sub>6</sub>H<sub>11</sub>),  
4.03 (2H, br s, OCH<sub>2</sub>), 4.51 (2H, d, C<sub>6</sub>H<sub>5</sub>CH<sub>2</sub>, J = 5.31 Hz),  
5.12 (1H, s, C(5)H), 6.56 (2H, br s, NH<sub>2</sub>), 7.20 (1H, br s,  
NH), 7.28-7.39 (5H, m, C<sub>6</sub>H<sub>5</sub>); m/z (+EI) 312 (M<sup>+</sup>, 100%),  
5 229 (M<sup>+</sup>-C<sub>6</sub>H<sub>11</sub>, 45), 216 (MH<sup>+</sup>-C<sub>6</sub>H<sub>11</sub>CH<sub>2</sub>, 53), 91 (72).

In general, there are a number of routes available  
for synthesising pyrimidine derivative in accordance with  
the invention which have a CDK inhibiting activity or  
which provide intermediates for preparing such CDK  
10 inhibiting compounds. By way of example some of the  
synthetic schemes that may be used, leading in some cases  
to new chemical entities, are illustrated in the  
following description of experimental details of typical  
stages of various synthetic schemes shown in schematic  
15 diagrams presented at the end of this description.

### Scheme 1

This illustrates the synthesis of 2-amino-4-  
cyclohexylmethoxy-6-di(4-methoxybenzyl)amino-5-pyrimidine  
carbaldehyde (NU6057) and the removal therefrom of either  
20 one or both benzylamino groups to give 2-amino-4-  
cyclohexylmethoxy-6-(4-methoxybenzyl)amino-5-pyrimidine  
carbaldehyde (NU6056) or 2,6-diamino-4-cyclohexylmethoxy-  
5-pyrimidine carbaldehyde (NU6055) respectively.

#### 1.1 Preparation of 2-Amino-4,6-dichloro-5-pyrimidine 25 carbaldehyde



Phosphorus oxychloride (21.6 ml; 0.236 mol) was cooled in an ice-bath (~ 5 °C) before slow addition of dry *N,N*-dimethylformamide (DMF, 7.0 ml) over 15 mins. No precipitate occurred as previously reported, and the reaction mixture was removed from the ice-bath. Commercially available 2-Amino-4,6-dihydroxypyrimidine (5.6 g; 0.044 mol) was added in small portions over 30 mins. The resulting suspension was heated at 90 °C for 1 h, then at 105 °C for a further 5 h. forming a red-brown solution which was chilled at 4 °C overnight. Distillation of 3-4 ml of excess phosphorus oxychloride at atmospheric pressure produced a viscous suspension which was poured into ice-water (100 ml). A gum formed which dissolved as the temperature of the water increased to 20 °C. Ammonium hydroxide was added dropwise until the solution reached pH 7 and a yellow precipitate formed which was collected by filtration. The product was recrystallised from ethyl acetate (5.15 g; 0.027 mol; 61%).

## 20 1.2 Preparation of Di-(4-methoxybenzyl)amine

To a solution of 4-methoxybenzaldehyde (3.0 g; 22 mmol) in dry ethanol (40 ml) was added 4-methoxybenzylamine (3.02 g; 22 mmol). The mixture was heated to reflux and heating continued for 1.5 h before removal of the solvent under reduced pressure. TLC analysis indicated that product and starting aldehyde co-elute at  $R_f$  0.8 (10% MeOH/DCM). No attempt was made to isolate the intermediate imine, instead the product was

dissolved in methanol (10 ml), to which sodium borohydride (0.834 g; 22 mmol) was added slowly with stirring. The reaction mixture was observed to reflux without additional heat, and was stirred for 1 h.  
5 Removal of the solvent yielded a pale yellow oil, which was further purified by column chromatography (100% EtOAc) affording a colourless oil which solidified on cooling to a white solid (5.31 g; 20.7 mmol; 94%).

10 **1.3 Preparation of 2-Amino-4-chloro-6-di-(4-methoxybenzyl)amino-5-pyrimidine carbaldehyde**

2-Amino-4,6-dichloro-5-pyrimidine carbaldehyde (0.50 g; 2.60 mmol) was stirred in dry DCM (5 ml). Triethylamine (0.263 g; 2.60 mmol) and di(4-methoxybenzyl)amine (0.669 g; 2.60 mmol) were added and  
15 the reaction stirred at r.t for 1.25 h. the reaction was worked up by addition of further DCM (50 ml) and extraction with saturated sodium chloride solution (3 x 50 ml). The organic layer was washed with water (50 ml), dried (MgSO<sub>4</sub>) and evaporated yielding a yellow foam (0.957  
20 g; 2.32 mmol; 89.2%).

In the next stage (1.4) the chloro substituent at position 4 of the pyrimidine ring is replaced by a cyclohexylmethoxy group. Two alternative methods (Method I and Method II) are described.

25 **1.4 Preparation of 2-Amino-4-cyclohexylmethoxy-6-di(4-methoxybenzyl)amino-5-pyrimidine carbaldehyde (NU6057).**

**(Method 1)**

Cyclohexylmethanol (8 ml) was heated with sodium (0.14 g; 6.06 mmol) at 90 °C for 1 h. 2-Amino-4-chloro-6-di(4-methoxybenzyl)amino-5-pyrimidine carbaldehyde  
5 (0.50 g; 1.212 mmol) was added and the mixture heated at the same temperature for 25 mins. Excess cyclohexylmethanol was removed by short path distillation under reduced pressure, and the residue loaded onto MgSO<sub>4</sub>. The dried product-MgSO<sub>4</sub>n was applied to a silica column,  
10 eluting with 40% EtOAc/ petrol (40:60). Product eluted along with some cyclohexylmethanol, which could not be separated. This mixture was taken through to the next stage.

**(Method 2)**

15 Sodium hydride (3 eq; 0.087 g; 3.6 mmol), dry dimethyl sulphoxide (3 ml) and cyclohexylmethanol (5.5 eq; 0.691 g; 6.1 mmol) were stirred under nitrogen for 30 mins until a clear solution had formed. 2-Amino-4-chloro-6-di(4-methoxybenzyl)-amino-5-pyrimidine  
20 carbaldehyde (0.50 g; 1.21 mmol) was added with stirring. Reaction mixture was heated at 100 °C for 2 h before removal of the solvent by short path distillation under vacuum. The residue was applied to a silica column eluting with 30% EtOAc/petrol. Product was isolated as a  
25 pale yellow solid (0.183 g; 0.37 mmol; 30.6%). M.p. 140-141°C.

Subsequently, either one or both of the benzylamino groups (acting as protective groups) are removed as described below (1.5 and 1.6) to form NU6056 or NU6055.

5      **1.5    Preparation of 2-Amino-4-cyclohexylmethoxy-6-(4-methoxybenzyl)amino-5-pyrimidine carbaldehyde (NU6056)**

The mixture of 2-Amino-4-cyclohexylmethoxy-6-di(4-methoxybenzyl)amino-5-pyrimidine carbaldehyde and cyclohexylmethanol obtained previously was stirred in  
10 trifluoroacetic acid (2 ml) for 18 h. Excess trifluoroacetic acid was removed, and the residue extracted with ethyl acetate and water (50 ml each). Further ethyl acetate was added to the aqueous layer, and the organic components combined, dried and evaporated.  
15 The residual brown oil was applied to a silica column, eluting with 20% EtOAc/petrol (40:60). A pale yellow oil was obtained. Addition and removal of acetonitrile gave a solid which was recrystallised from a petrol/ethyl acetate mixture (0.091 g; 0.34 mmol). M.p. 97°C.

20      **1.6    Preparation of 2,6-Diamino-4-cyclohexylmethoxy-5-pyrimidine carbaldehyde (NU6055).**

The mixture of 2-Amino-4-cyclohexylmethoxy-6-di(4-methoxybenzyl)amino-5-pyrimidine carbaldehyde and cyclohexylmethanol obtained previously was stirred in  
25 trifluoroacetic acid (2 ml) at 65 °C for 24 h. The same workup procedure was used as previously, with purification of the product by column chromatography

eluting with 40% EtOAc/petrol (40:60) yielding a pale yellow solid. M.p. 159-160°C.

## Scheme 2

This illustrates a slightly different scheme used to synthesis 2-Amino-4-cyclohexylmethoxy-6-dibenzylamino-5-pyrimidine carbaldehyde.

### **2.1 Preparation of 2-Amino-4-chloro-6-dibenzylamino-5-pyrimidine carbaldehyde.**

2-Amino-4,6-dichloro-5-pyrimidine carbaldehyde (0.15 g; 0.78 mmol) prepared as in Scheme 1 was stirred in dry dichloromethane (3 ml) at 0 °C. Dibenzylamine (1 eq; 0.78 mmol; 0.154 g) and triethylamine (1 eq; 0.78 mmol; 0.078 g) were added dropwise. The reaction was allowed to reach r.t, and stirred overnight by which time a clear solution had been obtained.

Further dichloromethane (50 ml) was added and the solution washed with saturated sodium chloride solution and water. The organic layer was dried and evaporated leaving a yellow solid (0.253 g; 0.72 mmol; 92.3%). M.p. 138-142°C.

### **2.2 Preparation of 2-Amino-4-cyclohexylmethoxy-6-dibenzylamino-5-pyrimidine carbaldehyde.**

Cyclohexylmethanol (10 ml) and sodium (5 eq; 0.163 g) were reacted at 90 °C for 1 h. 2-Amino-4-chloro-6-dibenzylamino-5-pyrimidine carbaldehyde (0.5 g; 1.42

mmol) was added and heating continued for 90 mins. Excess alcohol was removed by short path distillation under reduced pressure, and the product purified further by column chromatography. Product was shown to be  
5 contaminated with cyclohexylmethanol by visualisation of the alcohol with sulfuric acid spray (2%).

### Scheme 3

This illustrates a route for synthesising pyrimidine derivatives having substituted aralkyl or  
10 aralkene groups in the 5-position.

#### **3.1 2-Amino-4-chloro-6-dibenzylamino-5-(1-hydroxy-phenethyl)-pyrimidine.**

(Method based on that described in J. Org. Chem. 1958,  
15 23, 1783-1784).

2-Amino-4-chloro-6-dibenzylamino-5-pyrimidine  
carbaldehyde (0.10 g; 0.28 mmol), prepared as in Scheme  
2) was stirred in dry THF (10 ml) at 0 °C. Benzylmagnesium chloride (1.0 M; 3 eq; 0.85 mmol; 0.85  
20 ml) was added dropwise giving a yellow colouration which dissipated quickly. The reaction was stirred for 30 mins before addition of saturated ammonium chloride solution (50 ml) and ethyl acetate (50 ml). The aqueous layer was further extracted with ethyl acetate and the organic  
25 layers combined, washed with water, dried and evaporated. The product was purified by column chromatography eluting with 40% EtOAc/petrol (40:60) giving a pale yellow oil (0.086 g; 0.19 mmol; 68%).

3.2 Oxidation of 2-Amino-4-chloro-6-dibenzylamino-5-(1-hydroxyethyl)-pyrimidine to form corresponding 5-phenethylene derivative.

Oxalyl chloride (1.1 eq; 0.0016 g; 0.12 mmol) was  
5 added to dry DCM (5 ml) in a 3-necked flask fitted with a  
dropping funnel under nitrogen. The flask was chilled in  
a dry ice- acetone bath at -75-80 °C. A solution of DMSO  
(2.2 eq; 0.25 mmol; 0.02 g) in dry DCM was added dropwise  
over 5 mins and left stirring for 10 mins. A solution of  
10 2-Amino-4-chloro-6-dibenzylamino-5-(1-hydroxyethyl)-  
pyrimidine (0.05 g; 0.11 mmol) in dry DCM (5 ml) was  
added dropwise over 5 mins and the reaction left for 15  
mins. Triethylamine (5 eq; 0.56 mmol; 0.057 g) was added  
dropwise over 5 mins and the cooling bath removed. As  
15 the reaction warmed to room temperature, water was added  
(50 ml) and the organic layer separated. The aqueous  
phase was washed with further DCM (50 ml) and the  
organics combined, dried and evaporated. The product was  
loaded onto a silica column, eluting with 30 %  
20 EtOAc/petrol (40:60). This gave the product as a yellow  
oil (0.020 g; 0.05 mmol; 45 %), with recovery of some  
starting material (0.01 g).

For both the above products, which are intermediate  
compounds, the chloro substituent at position 4 of the  
25 pyrimidine ring may be replaced by a cyclohexylmethoxy  
group by the methods described in Scheme 1.

**Scheme 4**

This illustrates further examples of the synthesis of pyrimidine derivatives having dibenzylamine substituents in the 6 position and hydroxy or keto substituted alkyl, alkene, aralkyl or aralkene groups in the 5-position.

**4.1 Preparation of 2-Amino-4-chloro-6-di-(4-methoxybenzyl)amino-5-(1-hydroxy-phenethyl)-pyrimidine (R=Ph).**

10 2-Amino-4-chloro-6-di(4-methoxybenzyl)amino-5-pyrimidine carbaldehyde (0.20 g; 0.48 mmol) was stirred in dry THF (5 ml) at 0 °C. Benzyl magnesium chloride (1.0 M; 3 eq; 1.45 mmol; 1.45 ml) was added dropwise. The mixture was stirred for 30 mins before addition of  
15 saturated ammonium chloride solution (50 ml) and ethyl acetate (50 ml). The aqueous layer was further extracted with ethyl acetate and the organic layers combined, washed with water, dried and evaporated. The product was purified by column chromatography eluting with 40%  
20 EtOAc/petrol (40:60) giving a yellow oil (0.151 g; 0.30 mmol; 62.4%).

**4.2 Preparation of 2-Amino-4-chloro-6-di-(4-methoxybenzyl)amino-5-(1-hydroxyethyl)-pyrimidine (R=H).**

Procedure as above with 2-Amino-4-chloro-6-di(4-methoxybenzyl)amino-5-pyrimidine carbaldehyde (0.20 g;  
25 0.48 mmol) and 3.0 M methyl magnesium bromide (3 eq; 0.5



ml). Product obtained as a colourless glass (0.159 g; 0.37 mmol; 77%).

4.3 Oxidation of 2-Amino-4-chloro-6-di-(4-methoxybenzyl)amino-5-(1-hydroxyethyl)-pyrimidine (R=H) to form corresponding 5-ethenyl derivative.

Oxalyl chloride (1.1 eq; 0.039 g; 0.31 mmol) was added to dry DCM (5 ml) in a 3-necked flask fitted with a dropping funnel under nitrogen. The flask was chilled in a dry ice- chloroform bath at -60 °C. A solution of DMSO (2.2 eq; 0.62 mmol; 0.048 g) in dry DCM was added dropwise over 5 mins and left stirring for 10 mins. A solution of 2-Amino-4-chloro-6-di-(4-methoxybenzyl)amino-5-(1-hydroxyethyl)-pyrimidine (0.12 g; 0.28 mmol) in dry DCM (5 ml) was added dropwise over 5 mins and the reaction left for 25 mins. Triethylamine (5 eq; 1.4 mmol; 0.141 g) was added dropwise over 5 mins and the cooling bath removed. The reaction was allowed to warm to room temperature over 40 mins before addition of water (50 ml) and separation of the organic layer. The aqueous phase was washed with further DCM (50 ml) and the organics combined, dried and evaporated. The product was loaded onto a silica column, eluting with 40% EtOAc/petrol (40:60). This gave a yellow oil (0.031 g; 0.08 mmol; 24.5 %).

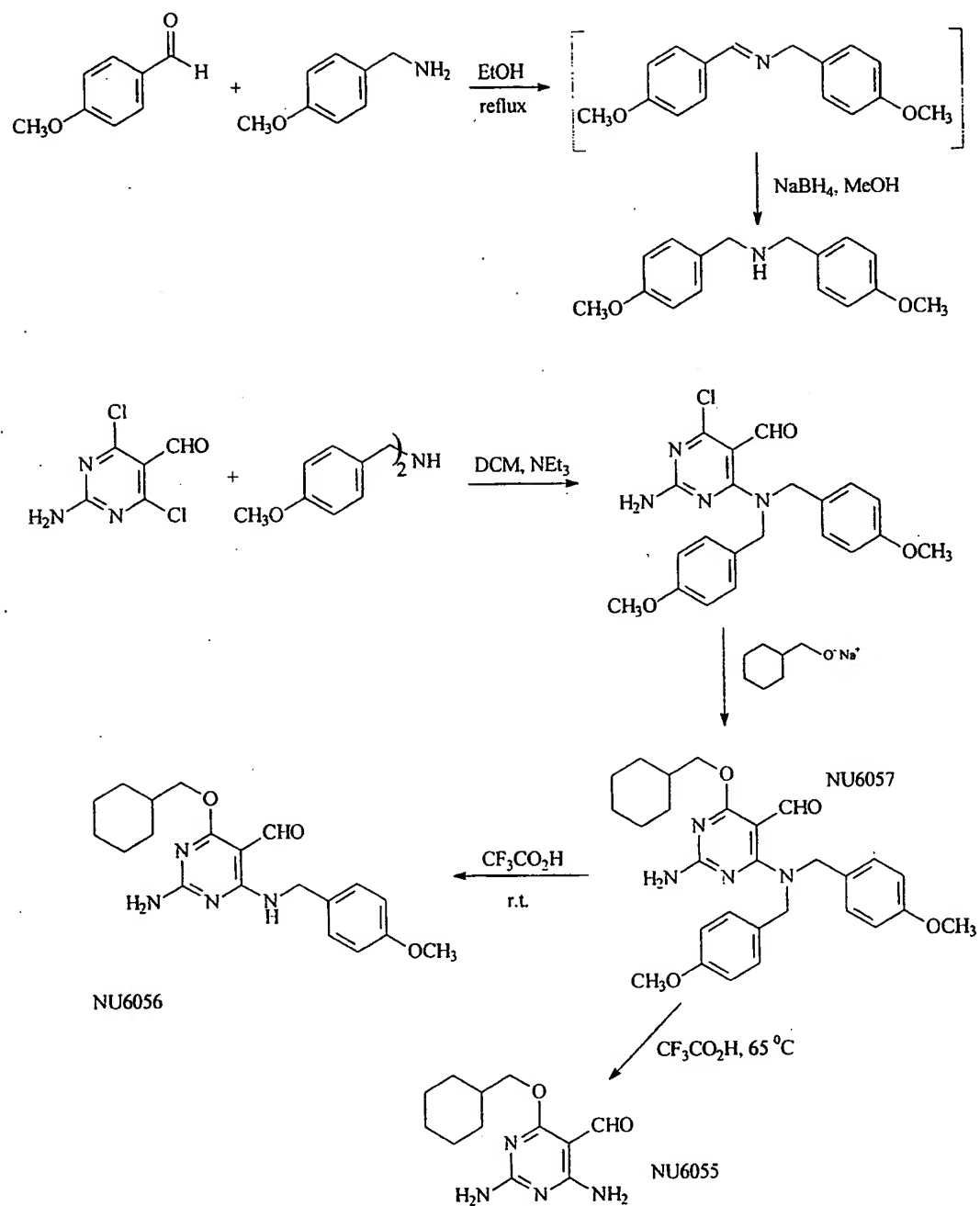
Again, the chloro substituent at position 4 of the pyrimidine ring may be replaced by a cyclohexylmethoxy group using the methods described in Scheme 1 to provide

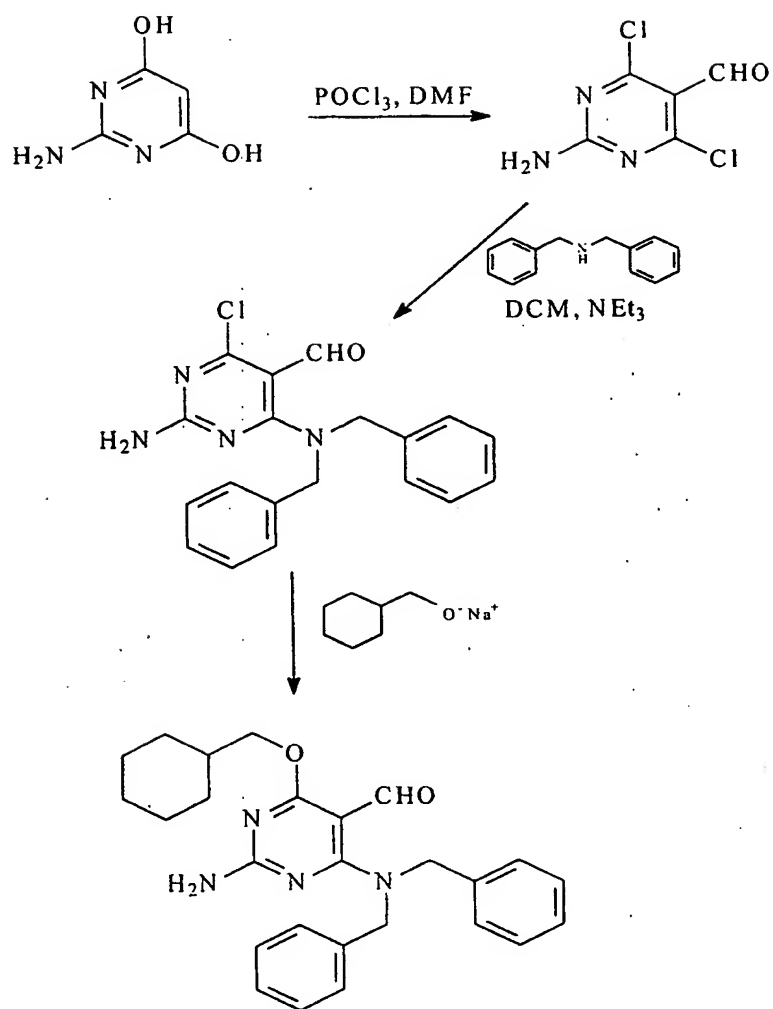
CDK inhibiting compounds in accordance with the invention.

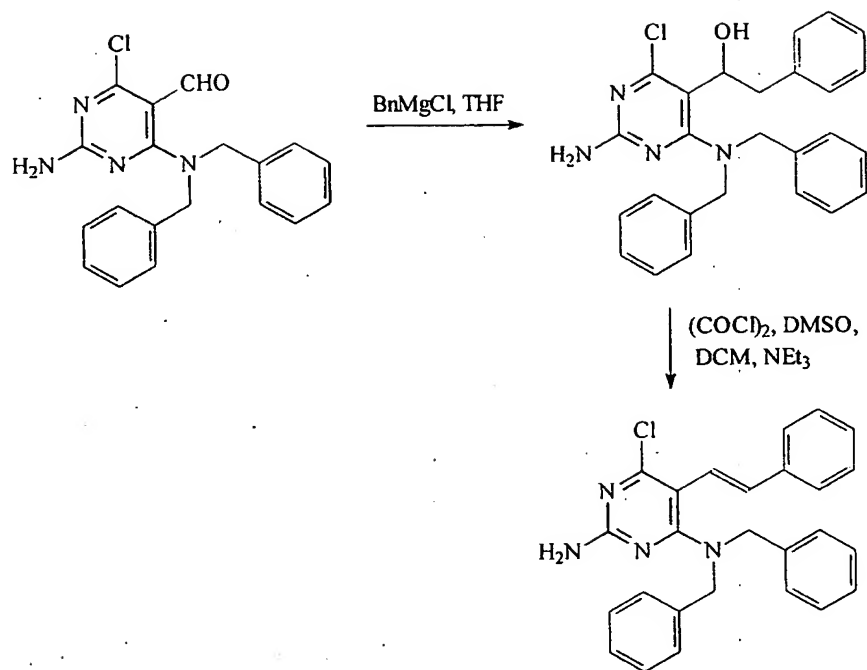
### Brief Summary

- 5           The present invention should be regarded overall as comprising each and every novel feature or combination of features disclosed herein but the main aspects of the invention broadly comprise, principally although not exclusively, the following:
- 10   (i)   Novel compounds of formula (I) as defined herein;
- (ii)   Compounds of formula (I) with substituents as hereinbefore defined (including pro-drug forms and salts thereof) for therapy or for use in medicine and in the manufacture of medical preparations,
- 15           useful for example as CDK inhibitors in treatment of cancer or other cell proliferation disorders.
- (iii)   Processes for the preparation of novel compounds of formula (I) as defined herein, including any novel intermediate compounds produced in carrying out
- 20           such processes;
- (iv)   Pharmaceutical compositions or formulations comprising a compound of formula (I) as defined herein together with a pharmaceutically acceptable carrier therein; and
- 25   (v)   Processes for the preparation of a pharmaceutical

formulation as defined in (iv) above, e.g. by methods referred to herein.

**Scheme 1**

Scheme 2

Scheme 3

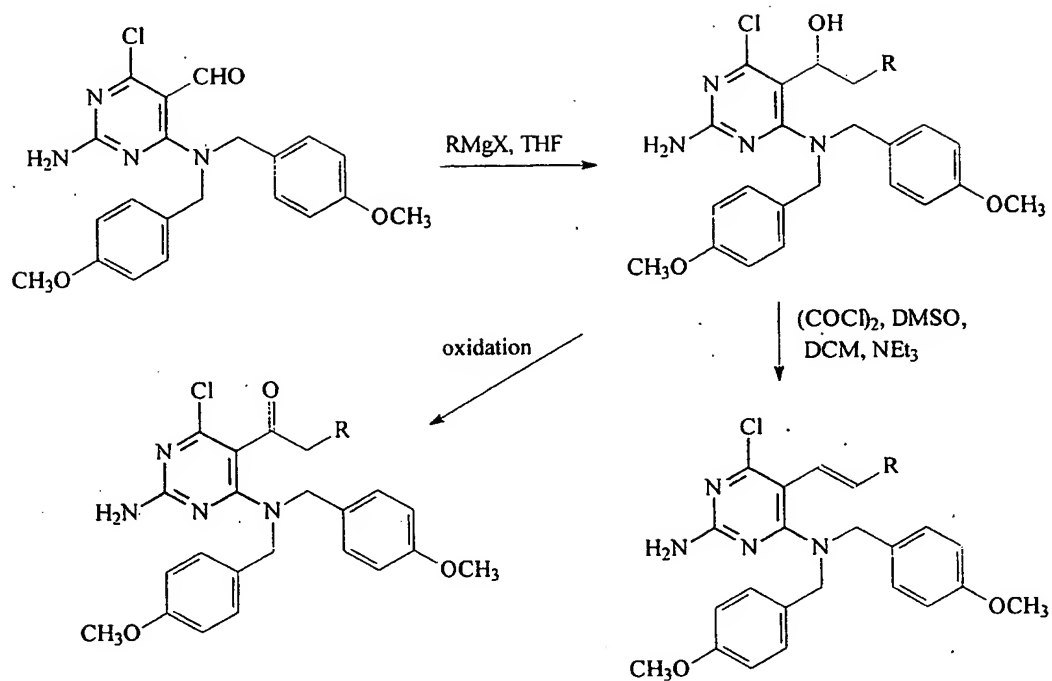
**Scheme 4**

Table 1

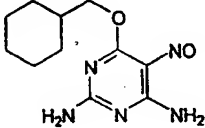
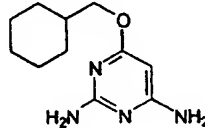
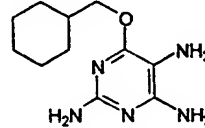
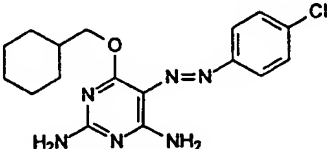
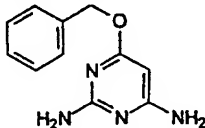
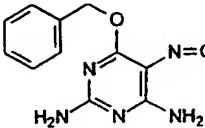
Number	Name	Structure	% inhibition or IC <sub>50</sub> (μM)		
			CDK1	CDK2	CDK4
NU6027	2,6-diamino-4-cyclohexyl-methoxy-5-nitroso-pyrimidine  C <sub>11</sub> H <sub>15</sub> N <sub>3</sub> O <sub>3</sub>  MW = 265.27		IC <sub>50</sub> = 2.4, 2.8	IC <sub>50</sub> = 2.2	
NU6034	C <sub>11</sub> H <sub>18</sub> N <sub>4</sub> O  MW = 222.29		4 ± 5 at 10 μM	7 ± 3 at 10 μM	
NU6035	C <sub>11</sub> H <sub>19</sub> N <sub>5</sub> O  MW = 237.30		40 ± 4 at 100 μM	54 ± 8 at 100 μM	
NU6037	C <sub>17</sub> H <sub>21</sub> ClN <sub>6</sub> O  MW = 360.84		3 ± 3 at 10 μM	6 ± 4 at 10 μM	
NU6038	C <sub>11</sub> H <sub>12</sub> N <sub>4</sub> O  MW = 216.24		Inactive	Inactive	
NU6039	C <sub>11</sub> H <sub>11</sub> N <sub>5</sub> O <sub>2</sub>  MW = 245.24		54 ± 9 at 100 μM	51 ± 2 at 100 μM	



Table 1 (contd)

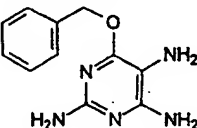
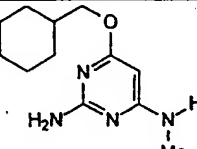
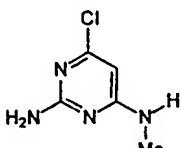
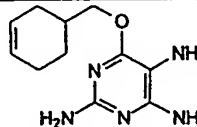
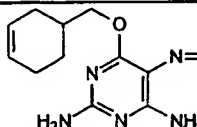
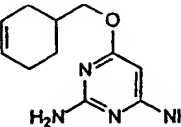
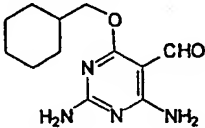
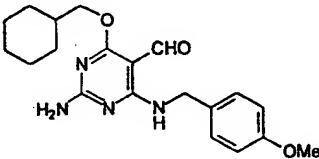
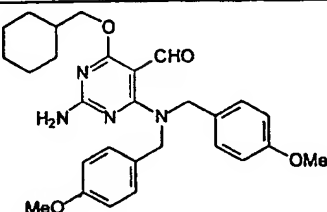
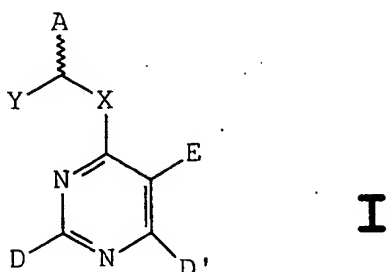
Number	Name	Structure	% inhibition or IC <sub>50</sub> (μM)		
			CDK1	CDK2	CDK4
NU6040	4-benzoyloxy-2,5,6-triaminopyrimidine C <sub>11</sub> H <sub>13</sub> N <sub>5</sub> O  MW = 231.25		Inactive	Inactive	
NU6041	2-amino-4-cyclohexylmethoxy-6-N-methylaminopyrimidine C <sub>12</sub> H <sub>20</sub> N <sub>4</sub> O  MW = 236.31		NT	NT	
NU6042	2-amino-4-chloro-6-N-methylaminopyrimidine C <sub>5</sub> H <sub>7</sub> ClN <sub>4</sub>  MW = 158.59		Inactive	Inactive	
NU6044	2,5,6-triamino-4-cyclohex-3-enylmethoxyxypyrimidine C <sub>11</sub> H <sub>17</sub> N <sub>5</sub> O  MW = 235.28		NT	NT	
NU6045	2,6-diamino-4-cyclohex-3-enylmethoxy-5-nitrosopyrimidine C <sub>11</sub> H <sub>15</sub> N <sub>5</sub> O <sub>2</sub>  MW = 249.27		IC <sub>50</sub> = 4, 5 μM	IC <sub>50</sub> = 6, 4 μM	
NU6046	2,6-diamino-4-cyclohex-3-enylmethoxyxypyrimidine C <sub>11</sub> H <sub>16</sub> N <sub>4</sub> O  MW = 220.27		16 ± 13 at 100 μM	8 ± 1 at 100 μM	

Table 1 (contd)

Number	Name	Structure	% inhibition or IC <sub>50</sub> (μM)		
			CDK1	CDK2	CDK4
NU6055	2,6-diamino-4-cyclohexyl-methoxypyrimidine-5-carbaldehyde  C <sub>12</sub> H <sub>18</sub> N <sub>4</sub> O <sub>2</sub> MW = 250.30		34 ± 4 at 10 μM		
NU6056	2-amino-6-(4'-methoxy-benzyl)amino-4-cyclohexylmethoxy-pyrimidine-5-carbaldehyde  C <sub>20</sub> H <sub>26</sub> N <sub>4</sub> O <sub>3</sub> MW = 370.45		NT	NT	
NU6057	2-amino-6-di-(4'-methoxy-benzyl)amino-4-cyclohexylmethoxy-pyrimidine-5-carbaldehyde  C <sub>28</sub> H <sub>34</sub> N <sub>4</sub> O <sub>4</sub> MW = 490.60		NT	NT	

CLAIMS

1. Use of a pyrimidine compound having the general structural formula I



or a pharmaceutically acceptable salt and/or prodrug form thereof for the manufacture of a medicament for use in therapy of mammals for treatment of tumours or other cell proliferation disorders susceptible to inhibition of one or more CDK enzymes, said pyrimidine compound being characterised in that in structural formula I

- 10           X    is O, S or  $\text{CHR}_x$   
               where  $R_x$  is H or  $\text{C}_{1-4}$  alkyl;
- D    is H or  $\text{NZ}_1\text{Z}_2$   
               where  $\text{Z}_1$  and  $\text{Z}_2$  are each independently H,  $\text{C}_{1-4}$  alkyl,  $\text{C}_{1-4}$  hydroxyalkyl, optionally substituted aryl or optionally-substituted aralkyl;
- 15           A    is selected from H,  $\text{C}_{1-4}$  alkyl,  $\text{C}_{1-4}$  alkoxy, hydroxy,  $\text{CH}_2(\text{CH}_2)_n\text{OH}$  ( $n=1-4$ ), and  $\text{NR}_{a1}\text{R}_{a2}$  where  $\text{R}_{a1}$  and  $\text{R}_{a2}$  are each independently H or  $\text{C}_{1-4}$  alkyl;
- 20           Y    is or includes an optionally substituted 4- to 8-membered carbocyclic or heterocyclic ring;
- D'   is H or  $\text{NZ}_3\text{Z}_4$

where  $Z_3$  and  $Z_4$  are each independently H,  $C_{1-4}$  alkyl,  $C_{1-4}$  hydroxyalkyl, optionally substituted aryl or optionally-substituted aralkyl;

5 E is selected from H, NO,  $NO_2$ ,  $N=N-Ar$  where Ar is an optionally substituted aryl or optionally substituted aralkyl,  $NR_{e1}R_{e2}$  or  $NR_{e1}NR_{e2}R_{e3}$  ( $R_{e1}$ ,  $R_{e2}$  and  $R_{e3}$  each being independently H,  $C_{1-4}$  alkyl,  $C_{1-4}$  hydroxyalkyl, an optionally substituted aryl or an optionally substituted aralkyl),  $C(R_e)=U$  ( $R_e$  being hydrogen,  $C_{1-4}$  alkyl or substituted alkyl, or an unsubstituted or substituted aryl or aralkyl, and U being  
10 selected from O,  $NR_e'$ ,  $NOR_e'$  and  $N-NR_e'R_e''$  where  $R_e'$  and  $R_e''$  are each independently H,  $C_{1-4}$  alkyl or  $CONH_2$ ), T,  $CH_2T$ ,  $CHT_2$  and  $CT_3$ , where T is a  
15 halide I, Br, Cl or F.

2. The use claimed in Claim 1 of a pyrimidine compound as defined therein in which Y comprises a ring structure that includes polar hydroxyl substituents.

20 3. The use claimed in Claim 1 of a pyrimidine compound as defined therein in which Y is a cycloalkane or cycloalkene ring.

4. The use claimed in Claim 3 of a pyrimidine compound as defined therein in which Y is a 5- or 6- membered  
25 cycloalkane or cycloalkene ring having one or two double bands.

5. The use claimed in Claim 4 of a pyrimidine compound

as defined therein except that one or two of the carbon atoms in the cycloalkane or cycloalkene ring are replaced by hetero atoms or groups.

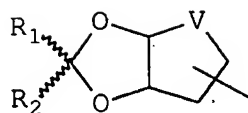
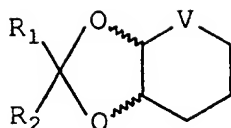
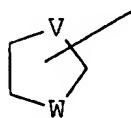
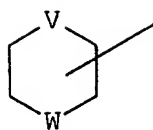
6. The use claimed in Claim 5 of a pyrimidine compound as defined therein in which said hetero atoms or groups are selected from O, S, NR' (where R' is H or C<sub>1-4</sub> alkyl) and (in a cycloalkene ring) -N=.

7. The use claimed in Claim 1 of a pyrimidine compound as defined therein in which Y is a substituted 4- to 8-  
10 membered carbocyclic or heterocyclic ring wherein the or each substituent is selected from H, C<sub>1-4</sub> alkyl, OH, C<sub>1-4</sub> alkoxy, halogen, CF<sub>3</sub>, CN, N<sub>3</sub> and NR<sub>y1</sub>R<sub>y2</sub> where R<sub>y1</sub> and R<sub>y2</sub> are each independently H or C<sub>1-4</sub> alkyl.

8. The use claimed in Claim 7 of a pyrimidine compound  
15 as defined therein in which two of the said substituents are on adjacent atoms of the ring and are linked to form an additional fused carbocyclic or heterocyclic ring structure.

9. The use claimed in Claim 1 of a pyrimidine compound  
20 as defined therein in which Y comprises a ring structure represented by one of the following structural formulae:

52



where V and W are each selected independently from

O, S, NR' (R' is H or C<sub>1-4</sub> alkyl)

and CH<sub>2</sub> or =CH-; and

5 R<sub>1</sub> and R<sub>2</sub> are each H or C<sub>1-4</sub> alkyl.

10. The use claimed in Claim 1 of a pyrimidine compound as defined therein in which D is an unsubstituted amino group and X is oxygen.

11. The use claimed in Claim 1 of a pyrimidine compound  
10 as defined in any of the preceding claims wherein each alkyl group present, either as such or as a moiety in an alkoxy or other group, contains 1-6 carbon atoms.

12. The use claimed in Claim 1 of a pyrimidine compound which is one of the following:

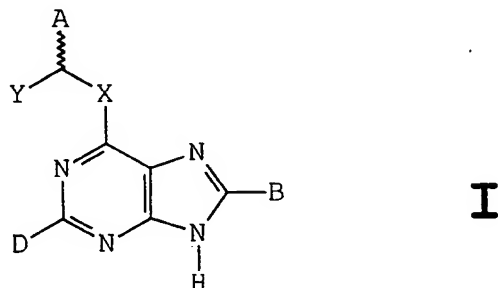
15

2,6-Diamino-4-cyclohexylmethoxy-5-nitroso  
pyrimidine;

2,5,6-Triamino-4-cyclohexylmethyloxypyrimidine;

2,6-Diamino-5-(4'-Chlorophenyl)azo-4-cyclohexyl  
methoxypyrimidine;  
2,6-Diamino-4-benzyloxy-5-nitrosopyrimidine;  
2,6-Diamino-4-cyclohex-3-enylmethyloxypyrimidine;  
2,6-Diamino-4-cyclohex-3-enylmethyloxy-5-nitroso  
pyrimidine;  
2-Amino-4-cyclohexylmethyloxy-6-methylamino  
pyrimidine;  
2-Amino-6-benzylamino-4-cyclohexylmethyloxy  
pyrimidine; and  
2,6-Diamino-4-cyclohexyl-methyloxypyrimidine-5-  
carbaldehyde.

13. A pyrimidine compound having the general structural  
formula I



or a pharmaceutically acceptable salt and/or prodrug form  
5 thereof,

characterised in that in structural formula I

X is O, S or  $\text{CHR}_x$

where  $\text{R}_x$  is H or  $\text{C}_{1-4}$  alkyl;

D is H or  $\text{NZ}_1\text{Z}_2$

10 where  $\text{Z}_1$  and  $\text{Z}_2$  are each independently H,  $\text{C}_{1-4}$   
alkyl,  $\text{C}_{1-4}$  hydroxyalkyl, optionally substituted  
aryl or optionally-substituted aralkyl;

- A is selected from H, C<sub>1-4</sub> alkyl, C<sub>1-4</sub> alkoxy, hydroxy, CH<sub>2</sub>(CH<sub>2</sub>)<sub>n</sub>OH (n=1-4), and NR<sub>a1</sub>R<sub>a2</sub> where R<sub>a1</sub> and R<sub>a2</sub> are each independently H or C<sub>1-4</sub> alkyl;
- 5 Y is or includes an optionally substituted 4- to 8-membered carbocyclic or heterocyclic ring;
- D' is H or NZ<sub>3</sub>Z<sub>4</sub> where Z<sub>3</sub> and Z<sub>4</sub> are each independently H, C<sub>1-4</sub> alkyl, C<sub>1-4</sub> hydroxyalkyl, optionally substituted aryl or optionally-substituted aralkyl;
- 10 E is selected from NO, NO<sub>2</sub>, N=N-Ar where Ar is an optionally substituted aryl or optionally substituted aralkyl, NR<sub>e1</sub>R<sub>e2</sub> or NR<sub>e1</sub>NR<sub>e2</sub>R<sub>e3</sub> (R<sub>e1</sub>, R<sub>e2</sub> and R<sub>e3</sub> each being independently H, C<sub>1-4</sub> alkyl, C<sub>1-4</sub> hydroxyalkyl, an optionally substituted aryl or an optionally substituted aralkyl), C(R<sub>e</sub>)=U (R<sub>e</sub> being hydrogen, C<sub>1-4</sub> alkyl or substituted alkyl, or an unsubstituted or substituted aryl or aralkyl, and U being
- 15 selected from O, NR<sub>e'</sub>, NOR<sub>e'</sub> and N-NR<sub>e'</sub>R<sub>e''</sub> where R<sub>e'</sub> and R<sub>e''</sub> are each independently H, C<sub>1-4</sub> alkyl or CONH<sub>2</sub>), T, CH<sub>2</sub>T, CHT<sub>2</sub> and CT<sub>3</sub>, where T is a halide I, Br, Cl or F
- 20

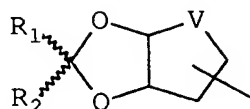
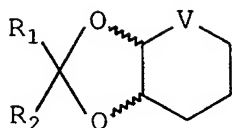
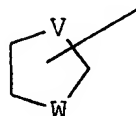
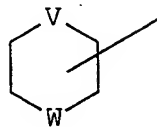
for use as an active pharmaceutical substance.

- 25 14. A compound as claimed in Claim 13 for use as an active pharmaceutical substance wherein the or each alkyl group present, either as such or as a moiety in an alkoxy or other group, contains 1-6 carbon atoms.



15. A compound as claimed in Claim 13 or 14 for use as an active pharmaceutical substance wherein Y comprises a ring structure that includes polar hydroxyl substituents.
16. A compound as claimed in Claim 13 or 14 for use as  
5 an active pharmaceutical substance wherein Y is a cycloalkane or cycloalkene ring.
17. A compound as claimed in Claim 13 or 14 for use as an active pharmaceutical substance wherein Y is a 5- or 6- membered cycloalkane or cycloalkene ring having one or  
10 two double bonds.
18. A compound as claimed in Claim 17 except that one or two of the carbon atoms in the cycloalkane or cycloalkene ring are replaced by hetero atoms or groups.
19. A compound as claimed in Claim 18 in which said  
15 hetero atoms or groups are selected from O, S, NR' (where R' is H or C<sub>1-4</sub> alkyl) and (in a cycloalkene ring) -N=.
20. A compound as claimed in Claim 13 or 14 for use as an active pharmaceutical substance wherein Y is a substituted 4- to 8- membered carbocyclic or heterocyclic  
20 ring wherein the or each substituent is selected from H, C<sub>1-4</sub> alkyl, OH, C<sub>1-4</sub> alkoxy, halogen, CF<sub>3</sub>, CN, N<sub>3</sub> and NR<sub>y1</sub>R<sub>y2</sub> where R<sub>y1</sub> and R<sub>y2</sub> are each independently H or C<sub>1-4</sub> alkyl.
21. A compound as claimed in Claim 20 in which two of the said substituents are on adjacent atoms of the ring  
25 and are linked to form an additional fused carbocyclic or heterocyclic ring structure.
22. A compound as claimed in Claim 21 in which Y

comprises a ring structure represented by one of the following structural formulae:



where V and W are each selected independently from

5 O, S, NR' (R' is H or C<sub>1-4</sub> alkyl)

and CH<sub>2</sub> or =CH-; and

R<sub>1</sub> and R<sub>2</sub> are each H or C<sub>1-4</sub> alkyl.

23. A compound as claimed in Claim 13 or 14 for use as  
an active pharmaceutical substance in which D is an  
10 unsubstituted amino group and X is oxygen.

24. A pyrimidine compound for use as an active  
pharmaceutical substance characterised in that it is one  
of the following:

2,6-Diamino-4-cyclohexylmethoxy-5-nitroso  
pyrimidine;

2,5,6-Triamino-4-cyclohexylmethoxypyrimidine;

2,6-Diamino-5-(4'-Chlorophenyl)azo-4-cyclohexyl  
methoxypyrimidine;

2,6-Diamino-4-benzyloxy-5-nitrosopyrimidine;

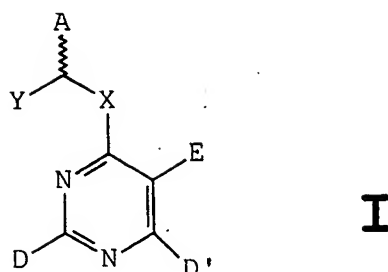
2,6-Diamino-4-cyclohex-3-enylmethyloxypyrimidine;  
2,6-Diamino-4-cyclohex-3-enylmethyloxy-5-nitroso  
pyrimidine;  
2-Amino-4-cyclohexylmethyloxy-6-methylamino  
pyrimidine;  
2-Amino-6-benzylamino-4-cyclohexylmethyloxy  
pyrimidine; and  
2,6-Diamino-4-cyclohexyl-methyloxypyrimidine-5-  
carbaldehyde.

25. A pharmaceutical formulation or composition containing a compound as claimed in any one of Claims 13 to 24 made up in unit dosage form for administration to a mammal in need of treatment with a CDK-inhibiting agent.

5 26. A pharmaceutical formulation or composition for medical use comprising an effective CDK-inhibiting amount of a compound as claimed in any one of Claims 13 to 24 together with a pharmaceutically acceptable carrier.

27. A pharmaceutical formulation or composition as  
10 claimed in Claim 25 or 26 for use in antitumour treatment.

28. A pharmaceutical composition for treatment of tumours or other cell proliferation disorders in mammals, said composition containing as the active ingredient a  
15 CDK-inhibiting pyrimidine compound having the structural formula I below:



or a pharmaceutically acceptable salt and/or prodrug form of said pyrimidine compound, characterised in that in structural formula I

- 5           X    is O, S or  $\text{CHR}_x$   
               where  $R_x$  is H or  $\text{C}_{1-4}$  alkyl;
- D    is H or  $\text{NZ}_1\text{Z}_2$   
               where  $\text{Z}_1$  and  $\text{Z}_2$  are each independently H,  $\text{C}_{1-4}$  alkyl,  $\text{C}_{1-4}$  hydroxyalkyl, optionally substituted aryl or optionally-substituted aralkyl;
- 10           A    is selected from H,  $\text{C}_{1-4}$  alkyl,  $\text{C}_{1-4}$  alkoxy, hydroxy,  $\text{CH}_2(\text{CH}_2)_n\text{OH}$  ( $n=1-4$ ), and  $\text{NR}_{a1}\text{R}_{a2}$  where  $\text{R}_{a1}$  and  $\text{R}_{a2}$  are each independently H or  $\text{C}_{1-4}$  alkyl;
- 15           Y    is or includes an optionally substituted 4- to 8-membered carbocyclic or heterocyclic ring;
- D'   is H or  $\text{NZ}_3\text{Z}_4$   
               where  $\text{Z}_3$  and  $\text{Z}_4$  are each independently H,  $\text{C}_{1-4}$  alkyl,  $\text{C}_{1-4}$  hydroxyalkyl, optionally substituted aryl or optionally-substituted aralkyl;
- 20           E    is selected from NO,  $\text{NO}_2$ ,  $\text{N}=\text{N}-\text{Ar}$  where Ar is an optionally substituted aryl or optionally substituted aralkyl,  $\text{NR}_{e1}\text{R}_{e2}$  or  $\text{NR}_{e1}\text{NR}_{e2}\text{R}_{e3}$  ( $\text{R}_{e1}$ ,  $\text{R}_{e2}$  and  $\text{R}_{e3}$  each being independently H,  $\text{C}_{1-4}$

alkyl, C<sub>1-4</sub> hydroxyalkyl, an optionally substituted aryl or an optionally substituted aralkyl), C(R<sub>e</sub>)=U (R<sub>e</sub> being hydrogen, C<sub>1-4</sub> alkyl or substituted alkyl, or an unsubstituted or substituted aryl or aralkyl, and U being selected from O, NR<sub>e</sub>', NOR<sub>e</sub>' and N-NR<sub>e</sub>'R<sub>e</sub>'' where R<sub>e</sub>' and R<sub>e</sub>'' are each independently H, C<sub>1-4</sub> alkyl or CONH<sub>2</sub>), T, CH<sub>2</sub>T, CHT<sub>2</sub> and CT<sub>3</sub>, where T is a halide I, Br, Cl or F.

10 29. A method of manufacturing a pharmaceutical composition for use in treating tumours or other cell proliferation disorders in mammals, said method comprising mixing an effective CDK-inhibiting amount of a pyrimidine compound as claimed in any one of Claims 13 to  
15 24, or a prodrug form thereof, with a compatible pharmaceutically acceptable additive, carrier, diluent or excipient.

30. A method of therapeutic treatment of a tumour or other cell proliferation disorder carried out on a  
20 mammal, said method comprising administering to said mammal an effective CDK-inhibiting amount of a compound as claimed in any one of Claims 13 to 24, or a pharmaceutical formulation or composition as claimed in any of Claims 25 to 28.

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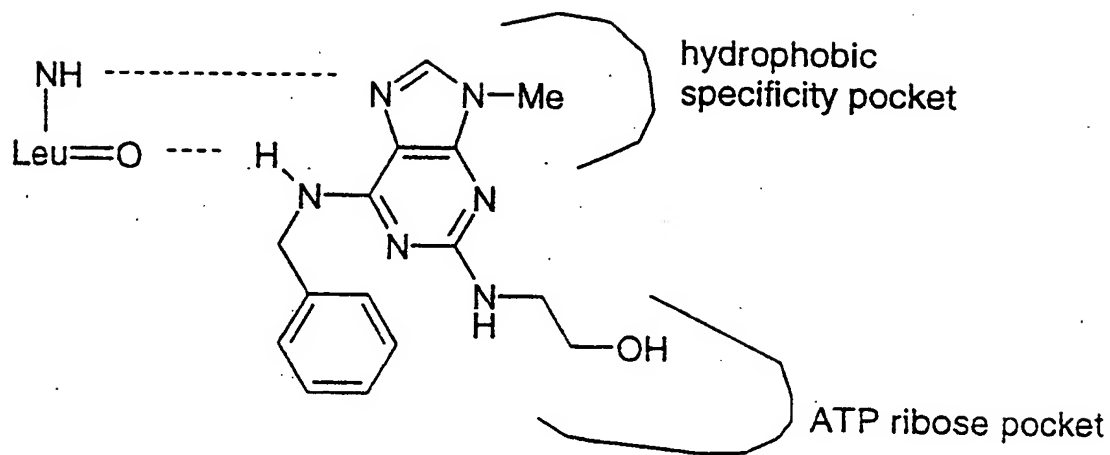
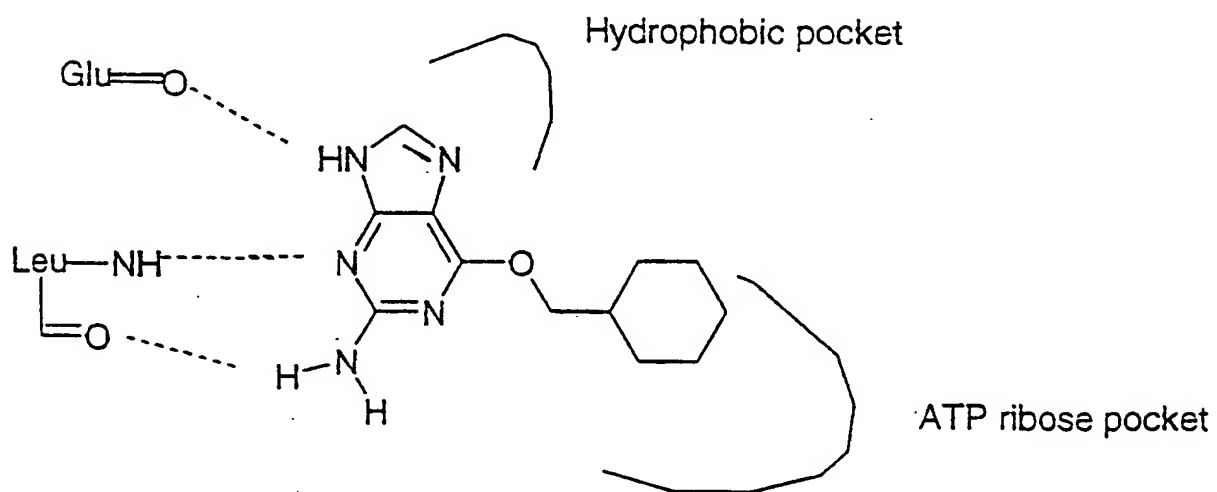
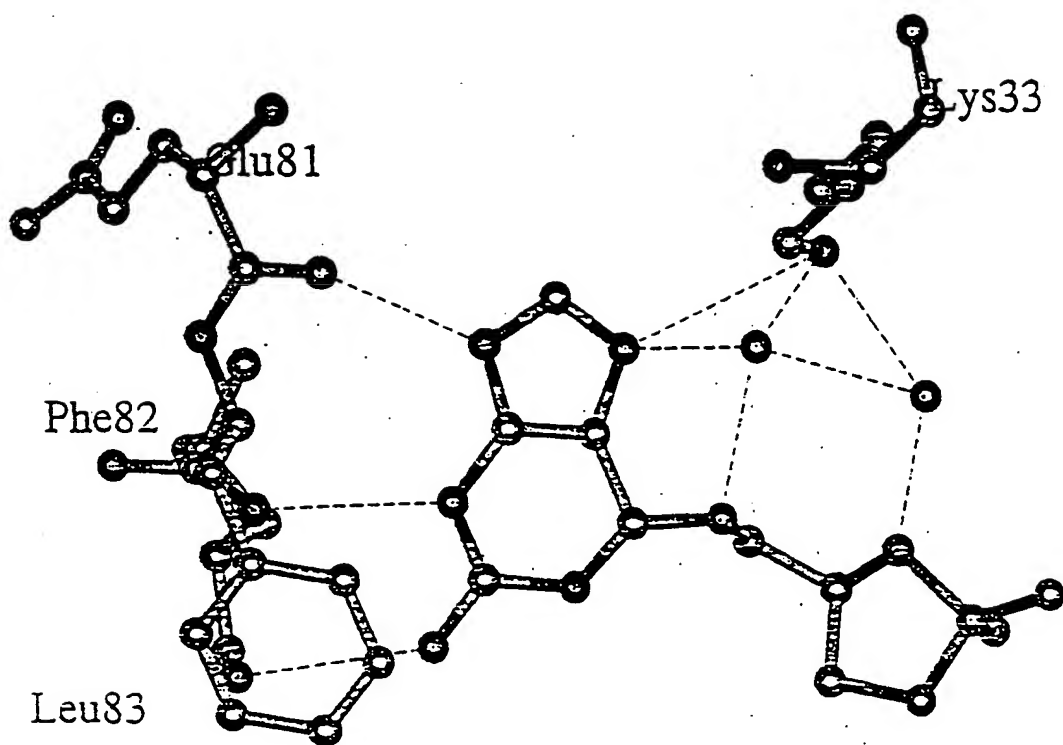
**FIGURE 1****FIGURE 2**

FIGURE 3





## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>C07D 239/50, 239/48, A61K 31/505, 31/52</b>		A3	(11) International Publication Number: <b>WO 99/50251</b>
			(43) International Publication Date: 7 October 1999 (07.10.99)
(21) International Application Number: PCT/GB99/00830 (22) International Filing Date: 29 March 1999 (29.03.99) (30) Priority Data: 9806739.0      28 March 1998 (28.03.98)      GB (71) Applicant (for all designated States except US): CANCER RESEARCH CAMPAIGN TECHNOLOGY LIMITED [GB/GB]; Cambridge House, 6-10 Cambridge Terrace, Regent's Park, London NW1 4JL (GB). (72) Inventors; and (75) Inventors/Applicants (for US only): GRIFFIN, Roger, John [GB/GB]; 6 St. Leonards Walk, Lancaster Park, Morpeth, Northumberland NE61 3SZ (GB). CALVERT, Alan, Hilary [GB/GB]; Beech House, Burn Road, Blaydon, Tyne & Wear NE21 6JR (GB). CURTIN, Nicola, Jane [GB/GB]; Vale View, Stirling Avenue, Rowlands Gill, Tyne & Wear NE39 1PK (GB). NEWELL, David, Richard [GB/GB]; The Dower House, Humshaugh, Hexham, Northumberland NE46 4AG (GB). GOLDING, Bernard, Thomas [GB/GB]; 6 The Copse, Burnopfield, Newcastle Upon Tyne NE16 6HA (GB). ENDICOTT, Jane, Anne [GB/GB]; 41 Hill View Road, Oxford OX2 0DA (GB). NOBLE, Martin, Edward, Mantyla [GB/GB]; 63 Mill Street, Oxford OX2		OAL (GB). BOYLE, Francis, Thomas [GB/GB]; Hinstock Mount, 22A Astbury Lane Ends, Congleton CW12 3AY (GB). JEWSBURY, Philip, John [GB/GB]; 28 Ashfield Road, Altrincham, Cheshire WA15 9QJ (GB). (74) Agent: WILSON GUNN SKERRETT; Charles House, 148/9 Great Charles Street, Birmingham B3 3HT (GB). (81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments. (88) Date of publication of the international search report: 3 February 2000 (03.02.00)	
(54) Title: CYCLIN DEPENDENT KINASE INHIBITORS			
(57) Abstract			
A range is disclosed of pyrimidine derivatives (I) which can act as inhibitors of cyclin dependent kinases (CDK's) and which thereby can provide useful therapeutic compounds for use in treatment of tumours or other cell proliferation disorders. The compounds of this invention bind to CDK molecules in a manner that appears to differ from that of known CDK inhibitors such as olomoucine and roscovitine.		<div style="text-align: right;">(I)</div>	



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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/00830

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C07D239/50 C07D239/48 A61K31/505 A61K31/52

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C07D C07C G03C A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CHAE M Y ET AL: "8-Substituted 06-benzylguanine, substituted 6(4) -(benzyloxy)pyrimidine, and related derivatives as inactivators of human 06-alkylguanine-DNA alkyltransferase" JOURNAL OF MEDICINAL CHEMISTRY, vol. 2, no. 38, 20 January 1995 (1995-01-20), pages 359-365, XP002079221 ISSN: 0022-2623 page 360; compounds 3a-f, 5a, 5b	1-12, 24-28
X	A.E. PEGG ET AL.: BIOCHEMICAL PHARMACOLOGY, vol. 50, no. 8, 1995, pages 1141-1148, XP002119932 the whole document	1-12, 24-28



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

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Date of mailing of the international search report

08/12/1999

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# INTERNATIONAL SEARCH REPORT

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ROBINS M J ET AL: "PURINE NUCLEOSIDES. XXIV. A NEW METHOD FOR THE SYNTHESIS OF GUANINE NUCLEOSIDES. THE PREPARATION OF 2'-DEOXY-ALPHA- AND -BETA -GUANOSINES AND THE CORRESPONDING N2-METHYL DERIVATIVES" JOURNAL OF ORGANIC CHEMISTRY, vol. 34, no. 7, 1 July 1969 (1969-07-01), pages 2160-2163, XP002028568 ISSN: 0022-3263 page 2161, exp. section, intermed.	1-12
X	SIYA RAM ET AL: "SYNTHESIS OF POTENTIAL ANTIFILARIAL AGENTS 2 1. METHYL 2 -SUBSTITUTED PURINE 8-CARBAMATES AND RELATED COMPOUNDS" JOURNAL OF HETEROCYCLIC CHEMISTRY, vol. 26, no. 4, 1 July 1989 (1989-07-01), pages 1053-1059, XP000578153 ISSN: 0022-152X examples 13-17; table 1	1-12,28
X	S.K. ROY ET AL.: DRUG METABOLISM AND DISPOSITION, vol. 24, no. 11, 1996, pages 1205-1211, XP002119933 the whole document	1-12, 24-28
X	WO 97 20843 A (MIDDLETON MARK ROSS ;RAFFERTY JOSEPH ANTHONY (GB); KELLY JANE (GB)) 12 June 1997 (1997-06-12) formula II, page 6; table 1A, page 49-50, 54	1-12,28
X	WO 96 04281 A (US GOVERNMENT ;ARCH DEV CORP (US); PENN STATE RES FOUND (US); MOSC) 15 February 1996 (1996-02-15) formula II, page 5; formula VI, page 8; examples 3,5, page 12	1-12,28
X	EP 0 806 418 A (NIPPON SHOJI KAISHA LIMITED) 12 November 1997 (1997-11-12) example 103	1-12,28
X	EP 0 661 286 A (LUCKY LTD) 5 July 1995 (1995-07-05) examples 1-6, page 13; 1-7, page 14	1-12,28
X	WO 93 09095 A (FISONS PLC ;FISONS CORP (US)) 13 May 1993 (1993-05-13) example 23	1-12
X	US 5 622 977 A (ALEXANDER RIKKI P ET AL) 22 April 1997 (1997-04-22) examples 31, 7d; interm. 7g, col.24	1-12,28
	-/--	

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/00830

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 017 466 A (KOBAYASHI HIDETOSHI ET AL) 21 May 1991 (1991-05-21) columns 11-12, example (25) ---	1-12
X	FR 2 416 228 A (POLI IND CHIMICA SPA) 31 August 1979 (1979-08-31) example 1 ---	1-12, 28
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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/00830

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	M.E. DOLAN ET AL.: CANCER RESEARCH, vol. 54, 1994, pages 5123-2130, XP002119934 the whole document ----	1
X	D.J. TRANTOLO ET AL.: JOURNAL OF MEDICINAL CHEMISTRY, vol. 29, 1986, pages 676-681, XP002119935 WASHINGTON US compounds 30,31 ----	1
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X	A. MARSH ET AL.: CHEM. COMMUN., vol. 13, 1996, pages 1527-1528, XP002119938 compounds 4-8,10 ----	1
X	H. ROKOS ET AL.: CHEM. BER., vol. 104, 1971, pages 739-747, XP002119939 compounds 4-6 -----	1

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/GB 99/ 00830

## Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 29 AND 30  
because they relate to subject matter not required to be searched by this Authority, namely:  
Remark: Although claims 29-30  
are directed to a method of treatment of the human/animal  
body, the search has been carried out and based on the alleged  
effects of the compound/composition.
2. ☒ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such  
an extent that no meaningful International Search can be carried out, specifically:  
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all  
searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment  
of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report  
covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is  
restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

## INTERNATIONAL SEARCH REPORT

International Application No. PCT/GB 99 00830

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.2

Claims Nos.: 1-12(part),28(part),13-27.

The structure formula in claim 13 contains a variable B which has not been defined either in the claim itself or in the description. No support can be found for this claim and the other claims depending thereon except figures 1 and 2 wherein B = H. Taking into account that the formula of claim 13 has received the same designation (I) as in claim 1 and that the groups defined are the same as in claim 1, in order to achieve a coherent search report, claim 13 has been understood as a "compound for use" claim directed to the compounds defined in claim 1 and to some extent to compounds encompassed by the structure given in claim 13 wherein B = H.

As to claim 1 and following dependent claims, the search revealed such a large number of particularly relevant documents, specially with regard to novelty, that the drafting of a comprehensive international search report cannot be achieved. Furthermore undefined expressions or terms like "optionally substituted", "Y includes", "prodrugs", "alkyl" or "aralkyl" hinder the comprehensibility of the search. Consequently the search has been essentially directed to the subject-matter as illustrated by the examples, in particular with the characteristics which appears essential to the invention wherein Y is a ring directly attached to the group -CH(A)-X-, and D always represents a (optionnally substituted) nitrogen atom. The cited documents are considered to form a representative sample of the state of the art.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

# INTERNATIONAL SEARCH REPORT

information on patent family members

Inter. Application No

PCT/GB 99/00830

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